THE S2 AUTOMATED AGENT (S2A2): A TRAINING AID FOR COMMANDERS AND INTELLIGENCE OFFICERS

by

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ABSTRACT

Although most leaders have a very solid background on the decision making process, training is still required to maintain and perfect their skills. While decision-makers and their staff can collectively train using computer simulations, there currently is no tool that allows the decision-maker to train in isolation on the decision-making process. If a decision-maker is to train in complete isolation without involving any of his staff, then there is a requirement to use artificial intelligence and its techniques to model the functions of the decision-maker's staff.

This research models some of the functions of one of the most critical staff officers in the United States Army, the military intelligence officer (S2). There have been many uses of artificial intelligence to support military operations, but there have been none to date that are proven to replicate the functions of an S2 during the processing phase of the intelligence cycle. This research begins the creation of an S2 automated agent (S2A2) that allows the commander to implement war plans and see the results of those plans. Systems model for both the learning environment and the S2A2 are developed. The S2A2 enables the commander to fight a simulated battle and receive intelligence reports and analysis so that he can modify his plan according to the enemy's

course of action. Further a S2A2 created in the research would not require that the actual human S2 be present if the S2A2 is set up by the S2 prior to the use by the commander.

The S2A2 is an expert system shell designed to operate in a Janus battlefield simulation and replicate the cognitive processes used by an S2 when making an intelligence assessment. The fundamental principle of the S2A2 is the decomposing of a complex problem, such as determining an enemy course of action, into smaller, more manageable situational indicators.

The S2A2 uses the procedures outlined in Army Field Manual 34-2, Collection Management and Synchronization Planning, as a guide for its hierarchical structure. This structure enables an S2 to define indicators, rules and rule sets for a particular previously defined enemy course of action. It also allows for the use of certainty factors to account for uncertain information.

In order for the commander to use the S2A2 in the Janus constructive simulation, an S2 must develop a complete intelligence preparation of the battlefield (IPB). Based upon that IPB, the S2 must generate a set of rules that pertain to each possible enemy course of action and input those rules into the S2A2. Since the S2 is required to complete his IPB prior to the simulation, the S2A2 can be used for any mission and on any piece of terrain. Once the simulation is run, the S2A2 reads Janus post-processing reports to determine which indicators and rules have become true. Finally, at a user specified time interval, the S2A2 will produce an assessment as to which course of action the opposing force is employing.

In demonstration, the S2A2 provided a correct and timely assessment indicating which course of action the enemy was adopting. The validation scenario used an opposing force motorized rifle brigade attacking a friendly battalion task force at the United States Army's National Training Center. The results of this validation scenario showed that the S2A2 has great potential as a tool to enable a commander to use an artificial intelligence system instead of having the S2 staff officer present

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ACRONYMS AND ABBREVIATIONS

AA – Avenue of Approach

AI – Artificial Intelligence

ASAS-RWS – All Source Analysis System – Remote Workstation

BDA – Battlefield Damage Assessment

CCIR – Commander's Critical Information Requirements

CF – Certainty Factor

COA – Course of Action

CoS – Chief of Staff

CSM – Command Sergeant Major

E – Evidence

EEIR – Essential Elements of Information Requirements

FFIR – Friendly Force Information Requirements

H - Hypothesis

HPT – High Payoff Targets

HUMINT – Human Intelligence

HVT – High Value Targets

I – Indicator

IMINT – Imagery Intelligence

IPB –Intelligence Preparation of the Battlefield

ISRA – Intelligent Simulation Reporting Agent

I&W – Indications and Warning

LB – Level of Belief

MRB – Motorized Rifle Brigade

NAI – Named Area of Interest

NLT – No Later Then

OCOKA – Observation, Cover and Concealment, Obstacles, Key Terrain, and Avenues of Approach

OPFOR – Opposing Force

R – Rule

RS – Rule Set

S2A2 – S2 Automated Agent

SIFT – Simulation Information Filtering Tool

SIGINT – Signals Intelligence

STRICOM – Simulation, Training and Instrumentation Command

TD – Time Difference

XO – Executive Officer

CHAPTER 1

INTELLIGENCE AND SIMULATION AS A TOOL FOR STAFF TRAINING

Introduction

In wartime, the goal of an Army organization is to fight and win battles. A commander of a unit does this by making battle plans to defeat the enemy. Those battle plans are translated into orders that subordinate commanders must in turn execute on the battlefield. A commander's plan, and the execution of the plan, are the primary factors that determine victory or defeat. Although the plan and execution play a major role in determining victory or defeat, the ability to adjust the plan based upon the current situation also plays a major role. The dynamic nature of the modern battlefield has a crucial effect on the outcome of any plan. A commander must be able to visualize the battlefield in order to modify his plan and thereby increasing the likelihood of success of the plan. There are several events that must occur for the commander to visualize the battlefield. First, he must have the appropriate manpower to gather critical information. Secondly, the critical information must be reported in a timely fashion. Thirdly, he must rapidly analyze the information so that he can modify the plan before predicted actions take place. Lastly, he must modify the plan, disseminate the plan and have subordinate units execute the modified plan. As we can see, the dynamic nature of the battlefield

poses many challenges to a commander. Some of those challenges may be eliminated using current technology and automation.

Artificial intelligence has long been a topic of interest to military planners and analysts alike. Using the computer to augment planning and analysis has great potential in both the military training and operations arena. This thesis will look at one application of artificial intelligence, the automating of the functions of a staff officer, in particular, the intelligence officer, for military planning, analysis and training.

Army Staffs

The United States Army is like many civilian organizations in that the organization is hierarchical in nature. Also like a civilian organization, a commander has a staff to help him accomplish his mission. The battalion is the lowest Army organization that has a complete staff that provides support to the commander. All other levels higher than a battalion also has a staff. The staff is responsible for providing a commander with assessments and analysis as well as providing support to subordinate commanders.

To provide some background on Army staffs it is important to understand how an Army unit is organized. An infantry battalion is used as the model because as mentioned earlier, it is the lowest Army organization to have a staff. A battalion is commanded by a lieutenant colonel and normally consists of four subordinate units, or companies. The battalion commander has a command sergeant major (CSM) and an executive officer (XO) to assist him in running the battalion. The CSM is responsible for providing advice

and assistance on all matters pertaining to enlisted personnel. The XO is a major and serves as the chief of staff (CoS). The staff consists of four separate sections that are responsible for providing support to companies and responding to the battalion commander on issues in their particular areas. Those sections are the personnel section (S1), the intelligence section (S2), the operations and training section (S3), and the logistics section (S4). Each staff section has a captain in charge with the exception of the S3 section, which normally has a major in charge.

Intelligence on the Battlefield

The intelligence section is responsible for all intelligence-related matters. Intelligence plays a vital role in the planning and execution of any Army operation. It is needed to determine enemy intentions and courses of action. Army units defeat the enemy by generating combat power at decisive times and places. Commanders use intelligence to predict and then verify when and where the decisive points will be on the battlefield, as well as to determine how much combat power to use in order to defeat the enemy. Intelligence is commonly referred to as the commander's eyes. A plan may be executed perfectly but if the intelligence that the plan is based upon is incorrect, then the plan will almost surely fail.

The intelligence cycle (Figure 1) is a continuous process by which information is analyzed and converted into intelligence. It consists of five phases: planning and directing, collecting, processing, producing, and disseminating. In the planning and

directing phase the intelligence required and who should collect it is determined. In the collecting phase, units are tasked to obtain combat information, intelligence, and targets.

Figure 1. The Intelligence Cycle

In the processing phase combat information is converted into a form that can be readily used to produce intelligence. The producing phase involves the integration, evaluation, analysis and synthesis of combat information into intelligence. The passing of intelligence and targets to users when they need them occurs during the dissemination phase (Army Field Manual 34-1).

There are six distinct functions that an intelligence officer or section must do during combat operations. The functions cover all five phases of the intelligence cycle. They are as follows:

- Provide Indications and Warning (I&W). I&W gives the commander as much early warning of hostilities as possible by determining indicators of an enemy course of action that in turn give the commander appropriate warning. The warning allows the commander to modify his plan based upon the enemy's intention. The actual process of providing I&W to a commander is done during the dissemination phase of the intelligence cycle.
- Intelligence Preparation of the Battlefield (IPB). IPB integrates the environment with the enemy's fighting doctrine. It reveals the enemy's capabilities and vulnerabilities and allows the commander to systematically predict his actions. It also helps the commander understand the battlefield and synchronize all battlefield operating systems for maximum effect. IPB is primarily conducted during the planning and directing phase of the intelligence cycle.
- Situation Development. Situational development confirms or denies enemy courses of action (COAs) predicted in the IPB. This enables the commander to make timely decisions. Situational development occurs during the producing phase of the intelligence cycle.
- Target Development and Target Acquisition. Target development and target acquisition is used to identify high value targets (HVTs) and high payoff targets

(HPTs) that support the commander's concept of the operation. Collection assets detect and locate those targets during the collection phase of the intelligence cycle with sufficient accuracy for attacks by fire, maneuver, and electronic means.

- Battle Damage Assessment (BDA). BDA gives the commander a continual assessment of enemy strength and the effect of a commander's operation on the enemy. The process by which BDA is devised is during the process and producing phases of the intelligence cycle.
- Force Protection. Force protection identifies those elements of a unit's force most important to an enemy force and those most vulnerable to detection and attack by enemy operations. It also limits the enemy's opportunities to engage friendly forces, and enables a commander to achieve maximum surprise on the battlefield. The identification of those elements is determined during the planning and directing phase of the intelligence cycle.

The responsibilities of an intelligence officer are great during the processing and producing phases of the intelligence cycle. The first thing the S2 must do is record each intelligence report into a general database. Next he evaluates the report according to seven criteria in order to determine if the intelligence is effective. Those criteria are relevant, usable, timely, accurate, complete, objective and predictive. After the report is evaluated the S2 next analyzes the report according to a common understanding of the battlefield. He uses this understanding of the battlefield to fill in high priority gaps in knowledge, to anticipate enemy decisions and to confirm enemy courses of action. The

amount of information that an S2 receives and has to analyze is enormous. The process that an S2 uses to analyze information is deliberate and very time consuming. Intelligence is time sensitive and if it is not acted upon in a timely manner the value of the intelligence is minimal. The S2 continually analyzes combat information and raw data to develop situations, develop or identify targets, assess battle damage, and give indications and warning of hostilities (Army Field Manual 34-8).

The Army has many different assets that are able to collect information on the battlefield. The S2 uses this information during the processing and producing phases of the intelligence cycle. The assets are divided into three distinct disciplines, human intelligence (HUMINT), signals intelligence (SIGINT) and imagery intelligence (IMINT) (Army Field Manual 34-1). HUMINT is the discipline that uses humans on the battlefield to collect information about the enemy. SIGINT uses systems to collect and analyze electronic communications and noncommunications on the battlefield. Lastly, IMINT uses imagery systems, either radar, infrared, optical or electro-optical, and analyzes the imagery to gather information on the enemy.

All Source Analysis System (ASAS)

The All Source Analysis System is a military intelligence information system that provides support to commanders. The Army considers ASAS as its premier intelligence analysis system. It receives information from all intelligence disciplines from various Army and national level collection assets. Although the division commander owns

ASAS, the information derived from ASAS is disseminated to commanders and staffs down to battalion level. According to the ASAS web site it "is the cornerstone of the Army's 'intelligence system of systems' supporting automatic intelligence analysis production dissemination and asset management." A major feature of ASAS is that it is able to receive information from multiple intelligence sources, fuse and correlate the information into a common picture of the battlefield. The common picture of the battlefield enables commanders to better comprehend enemy capabilities and intentions but does not automatically interpret any enemy actions. The intelligence analyst still must manually do the analysis. The fact that an intelligence analyst can now clearly see all intelligence reports on one computer screen certainly aids in the analysis and prediction of enemy intentions.

Knowbots

Mystech Associates, Inc. developed a system called Knowbots. Knowbots is a software system that enables the stimulation of the Army's All Source Analysis System-Remote Workstation (ASAS-RWS) through simulation of a scripted scenario taken from a training exercise. It uses communication systems that are in use today by the Army. Knowbots provides the commander with information that supports his critical information requirements (CCIR). CCIR is defined as "information of significant importance that must be brought to the commander's attention because of its potential impact on the decisions that he must make in order to be successful during an operation"

(Hodge, 1996). The CCIR are broken down into three categories: Priority Intelligence Requirements (PIR) – information about the enemy; Essential Elements of Friendly Information (EEFI) – information needed to protect friendly forces from the enemy's information-gathering systems; and Friendly Forces Information Requirements (FFIR) – information about the capabilities of the commander's units or adjacent units. Knowbots only answers one type of CCIR, the PIR. It "utilizes an expert system to intelligently filter through all available data that support the CCIR. The intelligent agent uses the knowledge base relevant and supporting information that may answer the CCIR request" (Carroll, 1996). The expert system component of Knowbots is tailored to a specific enemy situation. In order for it to work properly the enemy order of battle for the given scenario must be loaded into the expert system because the expert rules are scenario dependent. This makes Knowbots inflexible for all enemy forces and scenarios. This is not all that bad in itself. The concept of using an expert system for identifying enemy order of battle that relates to a specific PIR has many uses. Since in every training exercise the enemy scenario is different, it would be very time consuming and impractical to develop expert rules that are not scenario dependent. Also, expert rules that are too general do not have the required specific information to solve complex tasks.

Training Through Simulation

Simulation training has become the method of choice for staff training by today's Army leaders (Sturek, Williams, Connors, Creech, Janiszewski and Burton, 1997). Gone

are the days where massive numbers of soldiers are used as role players in order for commanders and staffs to train on decision-making skills. The budget and limited available training time don't support such training methods anymore. That reality has been the driving force behind the search for alternative training methods that has led the Army to employ simulation. Simulation offers many advantages:

- requires fewer soldiers; only the leaders go (about 50 vs. 700)
- uses no fuel or ammunition
- not restricted to training areas, land conflicts
- takes less time (since simulation allows faster than real-time training)
- offers "instant replay" and opportunity to train subtasks
- can train in all possible environmental conditions without danger

Using simulation is a very effective way to train commanders and staff at all levels on how to accomplish their wartime mission of planning and execution of military operations. It also saves money, saves time, and conserves manpower resources.

Janus Simulation Tool

Many simulations adapted for staff training have been developed to meet the commander's needs. One constructive simulation tools is called Janus. It is designed for brigade and battalion level staff training.

Janus is a high resolution model used for combat analysis. The model is an interactive, two-sided, closed, stochastic ground combat simulation. Interactive

> refers to the interplay between players who decide what to do in crucial situations during simulated combat and the system, which models that combat. Two-sided refers to the two opposing forces directed simultaneously by two set of players. Closed means that the disposition of opposing forces is largely unknown to the players in control of the other force. Stochastic refers to the way the system determines the results of actions such as direct fire engagement, according to the laws of probability. Ground combat means that the principle focus is on ground maneuver and artillery units (Salvetti, 1994).

Janus has been used for both the collective tasks for teamwork enhancement and special staff-specific skills. The commander's subordinate entities are represented in Janus with icons. The simulation role players take the instructions from commanders through their supporting staffs and enter commands (such as movement instructions) into Janus. Once set up, the "game" begins. Entities start executing their routes and an interactive combat situation develops. Routes can be modifies through interactive play.

To illustrate the process, here is an example (Sturek, et al., 1997). A battalion's mission may be to attack an objective area to the north. The battalion and its subordinate entities, all Janus icons, commence their attack along pre-designated routes. As they move towards their objective, they encounter enemy entities previously placed and defending the objective. As an enemy entity is detected on a friendly entity's line of sight, the enemy entity appears on the Janus screen. Based on the entity's behavioral attributes, they engage each other. If the friendly entity is a tank, it will acquire the

enemy entity at the range that its weapon systems are capable of in real life. Then, it will fire upon the enemy entity. Casualties are assessed and equipment is destroyed based on the situation, entity probability of hit and probability of kill assessments, and stochastic number draws.

Simulation Information Filtering Tool (SIFT)

SIFT is a tool that the United States Army Simulation, Training and Instrumentation Command (STRICOM) and the United States Army Artificial Intelligence Center developed to reduce information overload for an Army commander. It is a information filtering application available for decision-makers participating in a combat training simulation exercise with Janus. It works in conjunction with an Intelligent Simulation Reporting Agent that gathers information from Janus output files. In his master's thesis titled "The Simulation Information Filtering Tool (SIFT), An Information Filtering Application for Decision Makers Participating in Combat Training Exercises," Rodney L. Lusher (1997), developed and tested the use of SIFT with Janus and ISRA to reduce information overload for decision-makers in a simulation environment. The results of this work showed that SIFT can in fact reduce the number of messages that a commander receives by 86%, while retaining the information critical for successful decision making.

Concept of SIFT

SIFT reduces the number of messages that a commander receives by filtering the reports that are sent to the commander. The reports are filtered according to a set of criteria that the commander defines. SIFT used CCIR as the criteria. From the CCIR (phrased in questions), the staff develops indicators that will answer that critical question (PIR, EEFI, or FFIR). These indicators are the input into the SIFT/ISRA to set the information filters. When a report appears that matches the CCIR indicator's parameters, a report is generated and electronically mailed to the appropriate staff officer or commander.

Training the Commander in Complete Isolation

Although most commanders have a very solid background on tactical decision making, training is still required to maintain and perfect their skills. Routinely, commanders and their staff collectively train using computer battlefield simulations. These staff exercises require all staff officers to be physically present to provide estimates and recommendations to a plan. Normally setting up and running a computer battlefield simulation takes much time and effort by the commander, staff and support personnel. In order for a commander to train in complete isolation, without the need for any staff officers being physically present, there is a need for automation of staff officer functions in a combat simulation environment.

Training in complete isolation has many advantages for a commander. The

biggest advantage is that training in isolation reduces time and effort for staff and support personnel. Time is probably one of the most limited resource that a commander and staff have. Eliminating the staff and support personnel for a training exercise allows them to focus their time on other high priority activities. By reducing staff requirements during a simulation training exercise a commander is now free to implement strategies that he normally would not implement because of the limited time available. He can now devise multiple courses of action (COAs) and fight those COAs to determine which on is best for a given situation. Training in isolation also gives a commander the flexibility to train on tactical decision making skills whenever he has some free time during the day. He no longer has to coordinate a time for where all staff elements are present. A commander can simply train whenever he has some spare time. These advantages for training in isolation make the automation of staff officer functions in a combat simulation environment an attractive proposal.

CHAPTER 2

SIMULATING THE FUNCTIONS OF AN INTELLIGENCE OFFICER

Modeling the Functions of an Intelligence Officer

If a commander is to train in complete isolation without involving any staff officers, then there is a requirement to model the functions of a commander's staff. In a constructive, combat simulation, the primary role of the S2 is to receive combat information in the form of reports, evaluate the reports in order to determine if the information is effective, analyze the reports, and make an assessment. The process of making an assessment is not a trivial task. In fact, it is rather complicated. Quite often the utility of an S2 is measured in his ability to analyze data about the enemy and use it to make a correct assessment about the enemy course of action. It is clear to see why a good S2 is a very important asset to a maneuver commander. The assessment that an S2 makes and in turn the commander uses to implement his plan, could, if incorrect, result in the death of several hundreds of soldiers.

The cognitive process an S2 uses to make an assessment is not an inherited trait. Being able to make a correct assessment is a result of an S2's experience, his ability to think logically, practice and from countless hours of preparation. An S2 must also be an

expert on the enemy's capabilities, limitations and equipment in order to make a correct assessment. An opposing force is no different from the United States Army when it comes to tactical maneuver in that it has guides to tell how to operate in a given combat situation. The United States Army uses field manuals to outline how to perform in a given combat situation. These descriptions of how to operate are commonly referred to as doctrine. An S2 can acquire this knowledge about the enemy before hostilities even occur by studying the enemy's doctrine. Knowing the enemy's doctrine and equipment will allow an S2 to better analyze the enemy's courses of action. Therefore, if the goal is to allow the commander to train in isolation using a computer battlefield simulation environment, a model of the S2 should not only receive, evaluate and analyze information, it must be able to make a correct assessment based on the current enemy situation.

Automating the functions of an S2 is one step towards a commander being able to train on tactical decision making in complete isolation. While the S2 is just one portion of a commander's staff, future work must be done to automate all staff officers in order for a commander to conduct computer generated battles while requiring minimal staff officer support.

Artificial Intelligence Techniques

Artificial intelligence is defined as "the activity of providing such machines as computers with the ability to display behavior that would be regarded as intelligent if it

were observed in humans" (McLeod, 1998). Artificial intelligence attempts to make the computer reason like a human. It consists of several different disciplines that include expert systems, neural networks, perceptive systems, learning, robotics, AI hardware and natural language processing. The primary area of artificial intelligence that is pertinent to this thesis is the expert system.

Expert Systems

An expert system is defined as "a computer program designed to model the problem-solving ability of a human expert" (Durkin, 1994). An expert system consists of a knowledge base, working memory and an inference engine. It uses these three components to make a conclusion or recommendation about some problem. The knowledge base contains the knowledge of a human expert. It is similar to the expert's long term memory and is represented in the computer as facts, rules, concepts and relationships. The inference engine is a model of the expert's reasoning in the computer's processor. Working memory contains new information about a problem as a result of the reasoning process. It is similar to the expert's short-term memory (Durkin, 1994).

Expert systems are used for many different purposes that can be categorized by types of problem-solving problems. Some of those problems as outlined by Durkin (1994), are control, design, development, interpretation, prediction and selection. Since a model of the functions of an S2 includes receiving information, evaluating information, analyzing information and making an assessment from the information, the prediction

and interpretation capabilities of an expert system are perfect for the modeling of the functions of an S2.

Rule Based System

A specific type of expert system is the rule-based expert system. A rule-based expert system is "a computer program that processes problem-specific information contained in working memory with a set of rules contained in the knowledge base, using an inference engine to infer new information" (Durkin, 1994). A rule-based system is very simplistic in that it contains various rules which are composed of an antecedent (IF condition) and a consequent (THEN clause).

> Essentially, a rule-base is invoked by presenting the system with a specific problem description or case, and by the system searching through its knowledge of rules and facts for an answer. The mechanism used to draw conclusions based on the rules in the knowledge base and the data for the current case is contained in the system's inference strategy. The inference strategy specifies the order in which the rules will be compared to the knowledge base and a way of resolving the conflicts that arise when several rules match at once. (Lockheed Martin Corporation, 1997)

A rule based system uses two strategies to control the sequence of rule firing, forward chaining and backward chaining. Forward chaining is also known as a data driven strategy. This control strategy attempts to use current data or knowledge to solve a

specific problem. Normally forward chaining is used when there are more conclusions than data. It is often used when the expert first collects information about the problem and then uses the information to make a conclusion. Backward chaining is also known as goal driven. This control strategy looks first at the conclusion or goal and uses the knowledge to prove or disprove the goal. Normally backward chaining is used when there are far fewer conclusions than data. It is often used when the expert first considers a conclusion and attempts to prove the conclusion from the existing known data (Durkin, 1994).

Military Uses of Artificial Intelligence

While there have been numerous studies and articles written that describe the applications of artificial intelligence for the military, there have been very few that use an expert system to automate the functions of an S2 in a combat environment.

Expert System to Conduct Terrain Analysis

Richbourg and Olson (1996) discuss the use of a hybrid expert system that combines technologies for terrain analysis. Terrain analysis is a key component of the intelligence preparation of the battlefield (IPB). It is a process whereby the intelligence officer analyzes the military aspect of the terrain according to the acronym OCOKA. OCOKA stands for O - observation and fields of fire, C - cover and concealment, O - obstacles, K - key terrain and A - avenues of approach. The work of Richbourg and

Olsen describes a tool that uses several different artificial intelligence techniques for terrain analysis. The concept and techniques used include knowledge representation schemes, spatial reasoning techniques, autonomous agent planning methods, rule-based paradigms, and heuristic search strategies. The authors believe that "no single technique in isolation can fully solve the broad problems of the military operations planning, their combination provides a synergy that results in a useful end product" (Richbourg and Olson, 1996). Although the authors described a very effective method for using artificial intelligence to identify key terrain, which is a function of the S2 in the planning stage, they failed to outline a strategy for analyzing intelligence, which is the primary function of the S2.

Battlefield Reasoning

The best work done to date that looks the entire spectrum of military deliberate decision making process and the intelligence cycle was done by Major Jerry Lynn Schlabach (1997) in his thesis titled, The Illinois Architecture: A Framework that Provides New Opportunities for Battlefield Reasoning. In his thesis, Major Schlabach developed a procedural backbone that analyzes terrain, develops courses of action, conducts wargaming, develops intelligence requirements and produces intelligence. The architecture uses five separate blackboards that share information during the above-mentioned process. In doing this, three separate layers of terrain abstraction were used for battlefield reasoning. Major Schlabach believes that the nature of the terrain affects

all battlefield reasoning. The portion of his thesis that relates to the simulation of staff officer functions, specifically the S2, is the development of intelligence requirements and producing intelligence.

Resource Aware Virtual Enterprise Node (RAVEN)

The RAVEN is a suite of initiatives designed to solve the fundamental problem of information overload for intelligence analysts. It uses advanced reasoning and visualization technologies in a hybrid system that can be applied to all classes of military and non-military intelligence analysis. "RAVEN uses a traditional knowledge based expert system to build a military intelligence 'evidence tree' that can support both intelligence analysis and collection management" (Schlabach, 1997). The basic concept of RAVEN is quite ingenious. The S2 selects a priority intelligence requirement (PIR). RAVEN will then parse the PIR into specific information requirements. "RAVEN uses its knowledge base to access appropriate enemy Order of Battle (OB) files, enemy courses of action and terrain blackboards in the construction of a logic tree to support the selected PIR" (Schlabach, 1997). Major Schlabach contends that RAVEN accomplishes this task at a much faster rate then if the S2 were manually forming an evidence tree. This saving of time allows the S2 to concentrate on collection strategies.

While the concept described by Major Schlabach cannot be disputed, the actual implementation and evaluation of RAVEN had not been documented as of yet. He outlines several methods to implement, acquire knowledge and evaluate the conceptual

architecture. But since his work is just that, a conceptual architecture, the system is a long way from actually being used by decision-makers in a combat or simulated combat environment.

The Creation of an S2 Automated Agent

To allow a commander to train in isolation, there is a requirement for the development of an S2 automated agent. While there are many systems that support the commander with information, there are currently no systems, either fielded in the Army arsenal or in use with simulation systems, that can actually analyze the information and provide an intelligence assessment based on the current enemy situation. ASAS is a fielded information system that only provides correlated and fused data. It does not analyze the data; that is still left to the intelligence analyst. SIFT is a system that reduces information overload by prioritizing information according to the commander's critical information requirements (CCIR). Knowbots is a prototype system that is similar to SIFT in that it attempts to answer one of the CCIR, the priority information requirement (PIR). It uses an expert system to analyze data so that it can classify the data according to the PIR.

There have been many uses of artificial intelligence to support military operations, but there have been none to date that are proven to replicate the functions of an S2 during the processing phase of the intelligence cycle. The creation of an S2 automated agent will allow the commander to implement war plans and to see the results of those plans. It

will enable him to fight a simulated battle and receive intelligence reports and analysis so that he can modify his plan according to the enemy's course of action. The actual human S2 need not be present if the S2 automated is implemented.

A system that does analyze information and provide an intelligence assessment or estimate would be of great value for the both the commander and intelligence officer. The primary focus of the S2 automated agent is for use by the commander in a simulation combat environment to allow him to train on the decision-making process without the need for staff elements. The commander or S2 could also use the S2A2 to see how the positioning of intelligence collection assets can effect the amount of information received during a battle. The S2A2 could also improve an S2's ability to analyze intelligence by providing a means to assist him in thinking about what information is necessary in order to solve a complex problem like determining an enemy course of action. The functions of an S2 automated agent could also be used with currently fielded Army systems to help an intelligence officer rapidly analyze information and predict enemy courses of action in an actual combat situation.

Research Questions

Having determined that the development of an S2 automated agent that can analyze combat information and provide an intelligence assessment based on the current enemy situation is necessary, to allow a commander to train in complete isolation, the following research questions were developed.

1) What is the potential to enhance decision-making abilities by using artificial intelligence techniques to gather data and information from simulation systems?

2) Can an expert system that operates with a constructive simulation as an autonomous agent be developed to replicate the cognitive process used by an S2 to make assessments based on the current battlefield situation?

3) Can the expert system produce the expected output?

4) Can the expert system disseminate the results in a manner that potentially will give the decision-maker enough time to act upon the results?

CHAPTER 3

DESIGN AND DEVELOPMENT OF THE S2 AUTOMATED AGENT (S2A2)

Development of the S2 Automated Agent (S2A2)

In order to develop an S2 automated agent (S2A2) using an expert system as the artificial intelligence technique there are two major events that must occur. First and foremost the expert system that is going to represent the S2A2 must be designed and coded. Secondly the S2A2 must be tested. The methodology for each of these major events will be discussed.

Developing the Expert System

As you recall, an expert system is "a computer program designed to model the problem-solving ability of a human expert" (Durkin, 1994). It consists of a knowledge base, (facts, rules, concepts and relationships), inference engine and working memory. The output of an expert system is a recommendation or conclusion about some problem. The S2A2 or expert system must be able to represent or model a form of the cognitive processes used by an S2 in a computer simulated combat environment. Essentials

include being able to receive, evaluate and analyze information, and then use the information to provide an assessment on the enemy course of action (COA).

Before discussing the actual development of the S2A2, it is very important to discuss some underlining requirements of the S2A2. Since the purpose of the S2A2 is to allow the commander to train in isolation, the system must be able to function with the computer combat simulation that the commander uses to train. While there are many different computer combat simulations (Janus, Battalion/Brigade Simulation, ModSAF) in use today, research limitations restrict the S2A2 to an interface with the Janus simulation. Advantages to the interface include allowing the S2A2 to leverage the information parsing capabilities of SIFT/ISRA and isolate specific information that answers a commander's PIR. One disadvantage is that Janus does not model behavioral or cognitive semi-automated forces and future simulations are progressing towards this technology. A diagram of the Janus and SIFT/ISRA/S2A2 system architecture is at Figure 2.

It is crucial that a commander not be inundated with multiple software tools. To make it as easy as possible for the user (commander) the S2A2 will be integrated into already existing software in use by the commander, specifically SIFT/ISRA.

These requirements provide guidelines into the start of the development phase or knowledge engineering. During the knowledge engineering a very straightforward methodology was followed that includes two phases, knowledge acquisition and design.

Figure 2. Janus and SIFT/ISRA/S2A2 System Architecture

Knowledge Acquisition

The knowledge acquisition phase is generally the most difficult part of knowledge engineering. The author has been a tactical intelligence officer for over 10 years and has extensive knowledge on the intelligence cycle and the cognitive process that an S2 goes

through when making an assessment on a COA that the enemy is employing. For this reason the author will be serving as both the knowledge engineer and the domain expert. Army field manuals and current literature, such as Jane's Defense Weekly, will be used to collect information about an enemy's order of battle, equipment, doctrine and capabilities.

In a general sense it is important to note the inputs and outputs of the S2A2. The inputs to the S2A2 will be information that is gathered from SIFT/ISRA based upon indicators input into the S2A2. These reports can be either in the form of answers to a commander's PIR or intelligence reports that do not answer PIRs. The indicators input into the S2A2 are like the intelligence collection that is devised by the S2. The output of the S2A2 will be an intelligence assessment on the COA that the enemy is employing. The S2A2 output is similar to the output produced by an S2 after he receives and analyzes intelligence reports. The S2A2 is modeling the cognitive process used by the S2 to analyze combat information and make assessments based upon that information.

Design

During the design phase the following tasks as outlined by Durkin (1994) will generally be followed:

1. Select the knowledge representation technique,
2. Select the control technique,
3. Select the expert system development software,
4. Develop the expert system, and

5. Develop the user interface.

Knowledge Representation Technique

In order to choose the best knowledge representation technique for the S2A2, it is proper to first determine how an S2 mentally models the problem's knowledge. In most cases the S2 breaks down a problem (what is the enemy going to do) into many smaller problems. Using enemy doctrine as a guideline, the S2 has a good idea of how the enemy operates. He analyzes the terrain to determine how it can affect the enemy's deployment of equipment. He then creates indicators or particular pieces of knowledge that may help him gather more in depth knowledge about a situation. As an example, many opposing forces use common "Cold War" doctrine when attacking a defending enemy. The opposing force doctrine typically calls for maintaining a tank battalion consisting of 31 tanks as the reserve force. Their doctrine also says that they prefer to reinforce success as opposed to providing support to those elements that are not doing very well. Using this type of information the S2 can determine the main attack based upon the position of the reserve tank battalion. It is an indicator of the main attack. This type of mental model of the knowledge can be considered rule-based. The S2 uses IF/THEN statements to determine an assessment of an enemy course of action. For example, IF the reserve is following avenue of approach one (AA1) THEN the main attack will be along AA1.

Control Technique

There are three common types of control techniques, forward chaining, backward chaining and goal agendas. Forward chaining is used if an expert first collects knowledge and makes a conclusion from that knowledge. Backward chaining is used when the expert develops a hypothesis and attempts to prove or disprove the hypothesis. Goal agendas are used to document the problem solving approach used by the expert. To determine the appropriate control technique it is appropriate to determine how an S2 makes an assessment. The process is different based upon certain situations. Before a battle an S2 will attempt to gather as much information as possible about the enemy. He will use his knowledge about the terrain, enemy capabilities, equipment and doctrine, along with facts about the enemy (where specific units are located on the battlefield), to develop hypotheses about the enemy course of action. He is basically gathering as much information as possible and then making assessments based upon that information. Once a battle begins the process is entirely different. The S2 will use the initial hypotheses developed before the battle and gather information to prove or disprove each hypothesis. He will determine what information is unknown about the enemy and attempt to collect that information. New information will be used to either confirm or deny the original hypotheses about the enemy courses of action. As you can see, the process before a battle occurs is one that fits the forward chaining control techniques and during a battle is one that fits the backward chaining control technique. Since the purpose of the S2A2 is to

provide an assessment once the battle begins, the backward chaining control technique will be used to represent the S2's thought process.

Expert System Development Software

The selection of the development software is not a difficult task since most expert system software will be able to handle the specific nature of the problem that the S2A2 is attempting to solve. Power Model was chosen as the expert system shell for the S2A2. It is the software that is used by SIFT/ISRA and can handle all of the features of the problem (rule-based, inexact reasoning and backward chaining).

Develop the Expert System

The culmination of the design phase will be the actual development of the S2A2. An important consideration is how to fundamentally implement the S2A2. The two possibilities considered for implementation were to make the S2A2 as an expert system shell or as a "hard coded" system. Totally automating the S2A2 was not considered because of the complexity of the problem. To make the S2A2 totally automated would require programming the S2A2 against all possible enemy orders of battle and enemy contingencies. Additionally, a totally automated S2A2 must be able to analyze the terrain, like an actual S2, in order to make assessments as to which terrain is best for a given mission, for example defending or attacking. This is well beyond the resources and time available for this thesis. Hence, a totally autonomous S2 Agent is not feasible.

Developing the S2A2 as an expert system shell would allow an S2 to implement rules, based upon any enemy, conducting any mission, on any terrain. It would require the S2 to conduct some prior planning, and have a general knowledge of expert system logic, but would in turn be very flexible. This would be a semi autonomous approach in that the S2 would need to implement rules prior to an exercise but during an exercise not require any further intervention. Hence, once set up, the semi autonomous approach could support the commander in isolated training of a pre-established constrained set of scenarios.

Hard coding the expert system would consist of developing the S2A2 for a specific scenario. That is, against a specific enemy conducting a specific mission on a specific piece of terrain. As an example, developing the S2A2 for a scenario that consists of a Krasnovian style motorized rifle division attacking a defending brigade friendly force at the United States Army National Training Center. Although hard coding the S2A2 would be sufficient for a proof of concept, it would be very inflexible. The tradeoff therefore is flexibility versus prior planning. Implementing the S2A2 as an expert system shell was chosen because of the flexibility to use the S2A2 for any scenario.

Using the above constraints and ensuring that there is a clear understanding of the knowledge base, will be the key to success. The procedure used to design the expert system will follow the procedures outlined by Durkin (1994). Those procedures will be to define the problem, define the goals, define the goal rules, expand the system, and

refine the system. After these steps are complete the next step will be the development of the user interface.

The development of S2A2 procedures follows the actions outlined in Army Field Manual 34-2, Collection Management and Synchronization Planning, for an S2. In order to answer each intelligence requirement an S2 must first develop specific information requirement (SIR) sets. SIRs are detailed questions or pieces of information that when answered, can satisfy the larger intelligence requirement. They are used to break intelligence requirements into smaller, more specific and manageable questions. SIRs describe what information is required, where on the battlefield it can be obtained, and when it is to be answered. The S2A2 uses this procedure for the development of its rules.

The structure of the S2A2 is hierarchical in nature. It provides an answer to the question, which course of action (COA) is the enemy employing, by breaking down the problem into smaller pieces of information. A graphical representation of the S2A2 structure is shown in Figure 3.

Figure 3. S2A2 Structure

The lowest level of the S2A2 is an indicator. An indicator consists of types of equipment, a threshold count and a location on the battlefield. The S2 defines the specific type of equipment he is looking for in the equipment field of an indicator. The threshold count field allows the S2 to define the minimum number of pieces of equipment. The location field defines a specific location on the battlefield. The S2A2 uses NAIs to defined locations on the battlefield. The user should define NAIs before creating indicators. An example of an indicator is 31 T-72 tanks in named area of interest (NAI) 1. The S2A2 uses the indicators that the S2 defines for the defining of sub rules and ultimately rules.

A sub rule is a combination of indicators (or other sub rules) and an operand. There is no limit to the number of indicators (or other sub rules) and operands that a sub rule may contain. The S2A2 uses the logical OR and AND operands. It does not have

the capability to process the logical NOT operand. Sub rules also use parenthesis to group information. An example of a sub rule is as follows: (31 T-72 tanks at NAI 1 OR 20 BMPs at NAI 2) AND 10 BTRs at NAI 3.

A rule consists of an indicator (or sub rule), a time, and a certainty factor. Time is input in minutes by the user and is used to describe the elapsed time window for which all indicators in the rule must be true. In other words, if 30 minutes is input in the time field then all the indicators must be true within the same 30 minute time period. Certainty factors are used as a means to measure uncertain information or describe inexact reasoning. Durkin (1994) defines a certainty factor as a "number that reflects the net level of belief in a hypothesis given available information." The certainty factor is input as a percentage between –100 and 100. Certainty factors will be discussed in greater detail in the following sections.

A rule set consists of rules, a certainty factor and a level of belief. The same constraints that apply to certainty factors in rules apply to rule sets. A level of belief is a certainty factor derived through certainty factor arithmetic. More on levels of belief will be discussed in the section that outlines certainty factors. The rule set also adds an additional factor, sequencing. To date the S2A2 has not addressed the concept of sequencing. Sequencing is the order in which events must occur. The sequencing used in a rule set is really an implied logical AND. If a rule set consist of three rules, Rule1, Rule2, and Rule3, then the order in which the rules are listed coincide with the order in which the events must occur. Rule1 must become true before Rule2 and Rule3 become

true, and Rule1 and Rule2 must become true before Rule3 becomes true. Sequencing issues will be further detailed later in this chapter.

Finally, a COA consists of rule sets and a level of belief. There is no limit to the number of COAs used by the S2A2. The COA is the highest level of the S2A2 structure. It is what the S2A2 is trying to prove or disprove and provides the solution to the question that the S2 is trying to answer, what is the enemy doing on the battlefield.

The S2A2 uses monotonic reasoning with indicators. Monotonic reasoning as defined by Durkin (1994) is a "method of reasoning that assumes once a fact is asserted it cannot be altered during the course of the reasoning." This essentially means that once a fact or event becomes true, it remains true. In other words, if the enemy division reconnaissance force was observed at NAI 3, this fact (indicator) will remain true through the entire S2A2 reasoning process.

As mentioned previously, certainty factors are used to measure uncertain information. Certainty factors in their simplest form can be thought of as a measure of belief (or disbelief) for a given hypothesis. In the S2A2 certainty factors are used to determine the opposing force's (OPFOR) intent, which COA is being adopted, not as a means of evaluating reports for accuracy. Unlike the real battlefield, reports produced by Janus do not consider "the fog of war." All reports are completely accurate and in effect are perfect intelligence.

Durkin (1994) states that "certainty factors are not probabilities, but are informal measures of confidence for a piece of evidence. They represent the degree to which we

believe that the evidence is true." Certainty factors can be applied to both uncertain statements as well as rules. Table 1 (Durkin, 1994) outlines a way of representing uncertain statements in terms of a certainty factor. Using Table 1, the statement: the division main body is almost certainly attacking along avenue of approach (AA) 1 can be written as: the division main body is attacking along AA1 CF 0.8.

Table 1

CF Value Interpretation (Durkin, 1994)

Uncertain Term	CF
Definitely not	-1.0
Almost certainly not	-0.8
Probably not	-0.6
Maybe not	-0.4
Unknown	-.2 to .2
Maybe	0.4
Probably	0.6
Almost certainly	0.8
Definitely	1.0

Certainty factors are used with rules to represent the uncertain relationship between the evidence (E) in the premise and the hypothesis (H) in the conclusion. A general form of a rule is as follows: IF E THEN H CF(Rule). In the context of the S2A2 an uncertain rule could be: IF the division main body is at NAI 1 (E) THEN the enemy is attacking along AA1(H) CF(.6). The interpretation of the rule would be: If the division main body is at NAI 1, then the enemy is probably attacking along AA1.

Certainty theory arithmetic determines a level of belief (LB) in a hypothesis (a rule's conclusion) when the evidence in the rule's premise is uncertain. LB is the term used to distinguish certainty factors that are derived through certainty factor arithmetic from certainty factors that the user inputs. Three cases are considered, a rule has a single premise, a rule has multiple premises and more than one rule concludes the same hypothesis. For a rule with a single premise, IF E (CF (E)) THEN H CF(Rule), the LB in

the hypothesis H is calculated by multiplying the certainty factor value of the premise with the certainty factor of the rule.

$$LB(H, E) = CF(E)*CF(Rule) \tag{1}$$

An example using the rule, IF the division main body is at NAI 1 (E) THEN the enemy is attacking along AA1 (H), is as follows. If the positive evidence of the rule's premise E, the division main body is at NAI 1, has a certainty factor of .5 and the certainty factor of the rule is .8 then the LB in the rule's conclusion is 0.5*0.8 = 0.4. This can be translated as; maybe the enemy is attacking along AA1.

In the case of a rule that has multiple premises, certainty factor theory considers conjunctive and disjunctive rules. The general form of a conjunctive rule is: IF E_1 AND E_2 AND . . . E_i THEN H CF(Rule). The formula for calculating a LB for a conjunctive rule is:

$$LB(H, E_1 \text{ AND } E_2 \text{ AND} \ldots E_i) = \min \{CF(E_i)\}*CF(Rule) \tag{2}$$

The general form of a disjunctive rule is: IF E_1 OR E_2 OR . . . E_i THEN H CF(Rule). The formula for calculating a LB for a disjunctive rule is:

$$LB(H, E_1 \text{ OR } E_2 \text{ OR} \ldots E_i) = \max \{CF(E_i)\}*CF(Rule) \tag{3}$$

When more than one rule concludes the same hypothesis the general form is:

Rule 1- IF E_1 THEN H CF(Rule 1)

Rule 2- IF E_2 THEN H CF(Rule 2)

There are three cases to consider when determining a combined LB for a hypothesis. The LB for each rule can be positive, both can be negative, or one can be negative and one can be positive. The formulas for determining a combined LB for a hypothesis are detailed below.

$$LB_{2\ Combined}\ (CF_1, CF_2) = CF_1 + CF_2 * (1 - CF_1),\ \text{both} > 0 \tag{4}$$

$$LB_{2\ Combined}\ (CF_1, CF_2) = CF_1 + CF_2 * (1 + CF_1),\ \text{both} < 0 \tag{5}$$

$$LB_{2\ Combined}\ (CF_1, CF_2) = CF_1 + CF_2 / (1 - \min\ \{|CF_1|, |CF_2|\}),\ \text{one} < 0 \tag{6}$$

Equations 4 – 6 are used when there are two certainty factors to combine. When there are more than two certainty factors to combine the equations 7 - 9 are used:

$$LB_{n\ Combined}\ (CF_1, CF_2, \ldots CF_n) = LB_{n-1\ Combined} + CF_n * (1 - LB_{n-1\ Combined})$$
$$n > 2,\ LB_{n-1\ Combined},\ CF_n > 0 \tag{7}$$

$$LB_{n\ Combined}\ (CF_1, CF_2, \ldots CF_n) = LB_{n-1\ Combined} + CF_n * (1 + LB_{n-1\ Combined})$$
$$n > 2,\ LB_{n-1\ Combined},\ CF_n < 0 \tag{8}$$

$$LB_{n\ Combined}\ (CF_1, CF_2, \ldots CF_n) = LB_{n-1\ Combined} + CF_n / (1 - \min\ \{|\ LB_{n-1\ Combined}\ |, |CF_n|\})$$
$$n > 2,\ \text{one} < 0 \tag{9}$$

Certainty theory for rules using equations 4-9 follows the commutative and asymptotic properties. The commutative property assures that a combined certainty factor value for a hypothesis is not dependent upon the order of the processing rules when more than one rule gathers information. The asymptotic property is used to incrementally add belief to a hypothesis as new evidence is obtained and to ensure that the certainty value of a hypothesis does not exceed 100% (or –100%).

In the S2A2 certainty factors are associated with indicators, rules, and rule sets. The user inputs certainty factors for rules and rule sets. Although the user does not input a certainty factor for an indicator, each indicator has an implied certainty factor of 100%. Additionally, rule sets and COAs have a LB which is derived through certainty factor arithmetic from the certainty factors of rules and rule sets.

The S2A2 can use both singular and multiple rules sets to determine a LB about a COA. As evidence is gathered, rules and rule sets become true. That is, evidence is gathered and when a rule or rule set's premise is met, the rule or rule set concludes information.

An example of the calculation of a LB for a COA based upon the certainty factors of rules and rule sets will be outlined. It is important to visualize the hierarchical organization of the S2A2 when looking at certainty factor arithmetic. An example of the hierarchical organization of the S2A2 with two COAs is listed in Table 2.

Table 2.

Hierarchical Organization of S2A2

COA 1	Certainty Factor		COA 2	Certainty Factor
RS1	.7		RS3	.8
R1	.95		R6	.92
R2	.9		R7	.95
R3	.93		RS4	.7
RS2	.6		R8	.93
R4	.94		R9	.96
R5	.90		R10	.95

The organization of the S2A2 in table 2 can be written in standard rule based form as:

IF RS1 THEN COA1

IF R1 AND R2 AND R3 THEN RS1

IF RS2 THEN COA1

IF R4 AND R5 THEN RS2

IF RS3 THEN COA2

IF R6 AND R7 THEN RS3

IF RS4 THEN COA2

IF R8 AND R9 AND R10 THEN RS4

Based upon table 2 as an example, there are only conjunctive rule sets and not disjunctive rule sets. Sequencing was introduced in the previous discussion of rule sets. Sequence within a rule sets is an implied logical AND. For that reason all rule sets will be conjunctive. The conjunctive rule sets are as follows:

IF R1 AND R2 AND R3 THEN RS1 CF(.7)

IF R4 AND R5 THEN RS2 CF(.6)

IF R6 AND R7 THEN RS3 CF (.8)

IF R8 AND R9 AND R10 THEN RS4 CF (.7)

Assuming that all rules have become true, equation 2 can be used to determine a LB for each rule set. The LB for each rule set is as follows:

LB RS1 = min (.95, .9, .93)* .7 = .63

LB RS2 = min (.94, .9)* .6 = .54

LB RS3 = min (.92, .95)* .8 = .7363

LB RS1 = min (.93, .96, .95)* .7 = .651

Again basing table 2 as an example there are more than one rule sets concluding the same COA. Rule set 1 and 2 both conclude COA1 and rule set 3 and rule set 4

conclude COA2. Using the calculated LB for each rule set from above and equation 4 we can calculate a LB for each COA.

LB COA1 =.63 + .54 * (1 - .63) = .8298

LB COA2 = .7363 + .651 * (1 - .7363) = .908

There are two other features of the S2A2. The first relates to what constitutes an assessment that the OPFOR is adopting a particular COA. This ties in directly to the certainty factor discussion above. The user is allowed to input a certainty factor value that serves as a threshold. If a COA associated LB value meets or exceeds this threshold the S2A2 will report that the OPFOR is adapting that COA. The user is also allowed to determine how often the S2A2 should report its results by inputting a time value in minutes.

Several issues arose during the development of the S2A2 that related to sequencing of events or temporal relations. Those issues were how to represent the sequencing of events on the battlefield and what logically does the sequencing of events really mean. The way an S2 sequences events must be looked at in order to solve the first issue. An S2 develops an event matrix that lays out how he anticipates events on the battlefield to occur. The event matrix is a relationship between different OPFOR activities (events on the battlefield) and the time the S2 expects those events to occur. It was important to include this capability into the S2A2 because this is actually how an S2 thinks about events. There is a caution when using this feature though. The S2A2 will evaluate only the first untrue rule of the rule set. If the first rule remains untrue then the

other rules within the rule set will not be evaluated. If the rule set had, lets say, five rules, and the first rule never became true than all the other rules would never be evaluated. If the other four rules were actually true then the S2A2 would not recognize this fact. If the user wishes not to include the sequencing of events all that is necessary is to create multiple, one-rule rule sets. To reduce the risk of the sequencing the user can also use a combination of sequenced rules and non-sequenced rules.

The other issue was to define the meaning of event sequencing. In the case where events are discrete, this is a not an issue because one event becomes true before another event. In the non-discrete case, or the case where events have associated intervals, which occurs in the S2A2, the issue is not so simple. The events are non-discrete in the S2A2 because rules have an associated interval or time window. The S2A2 counts equipment types as defined by an indicator over a specified period of time and it is likely that different rules within a rule set will have different time windows. Each rule will have a time associated with when the first piece of equipment in an indicator was counted and a time when the equipment count of the indicator met or exceeded the threshold. This will be referred to as a time interval for a rule to become true. There are thirteen different temporal relationships that can occur when thinking about the sequencing of two rules in the S2A2 (Allen, 1983). Those relationships are as follows:

1. The time interval for rule A occurs before the start of the time interval for rule B. Pictorially this case looks like |_A_| |_B_|.

2. The time interval for rule A ends at the same time that the time interval for rule B starts. | A | B |

3. The time interval for rule B starts sometime within the time interval for rule A and ends after the time window for rule A ends.

```
|  A  |
    |  B  |
```

5. The time intervals for rule A and rule B end at the same time and the time interval for rule A starts after the time interval for rule B starts.

```
         |_A_|
|_______B___|
```

6. The time interval for rule A and rule B start at the same time but the interval for rule A ends before the time interval rule B ends.

```
|__A__|
|___B____|
```

7. The time interval for rule A is contained within the time interval for rule B.

```
   |_A_|
|___B____|
```

8. The time intervals for rule A and rule B are the same.

```
|___A____|
|___B____|
```

The six other cases are the same as 1 – 6 except the rules are reversed. Since rule A must become true before rule B becomes true cases 4 – 13 were eliminated. Therefore the S2A2 only considers sequencing as either case 1, case 2 or case 3.

The last issue to discuss in the development of the S2A2 is process used by the S2A2 to evaluate a COA. The S2A2 uses the backward chaining control technique. Specifically the S2A2 uses a depth-first search when evaluation COAs. Durkin (1994) defines depth-first search as "a search techniques that looks for a solution along each branch of a problem space to its full vertical length, then proceeds in some defined order

such as from left to right." An interim evaluation of a subset of active indicators using this technique is done every 60 seconds (of simulation time) to ensure that the S2A2 does not exclude any rule that may have become true. This indicators subset is determined by starting with each of the COAs and then sequentially tracing down the hierarchy through the highest priority non-true rule of each non-true rule set to every indicator used in the rules that are thus reached. The records in each indicator thus triggered are checked to determine the total number of unique elements that are recorded within the time window set by the rule that is using it. If that number is at least as large as the threshold (from the indicator), that indicator is set as true for the rule being evaluated. If that particular rule has evaluated enough of its indicators that it has also been set to true, it evaluates each of its indicators for removal from the list of active indicators. If any of its indicators is not still needed by another rule, either currently or potentially in the future, those unneeded indicators are removed from the list of active indicators. (Once a rule is set as true within a rule set, it remains as true within that rule set from then on, but only within that rule set. If the rule is used in another rule set and has not been set as true in that other rule set, it is still non-true within that other rule set.) Rules that have not been set to true after all of their indicators have been evaluated remain as non-true for evaluation at the next interim indicator/rule evaluation. At the completion of the interim indicator/rule evaluations, all indicators remaining on the list of active indicators are reset to non-true. Note that the remaining list of active indicators includes all indicators that are needed by every currently non-true rule.

After a rule set and all of its associated rules are evaluated, the S2A2 performs certainty factor arithmetic to determine a level of belief for the rule set. After the rule set level of belief is determined, it is added to the level of belief of its associated COA. This process is repeated for all rule sets and in every COA. A complete discussion on the development of the S2A2 is at Appendix A.

Development of the User Interface

To make the system as user friendly as possible information will be gathered from commanders or past commanders about the type of interface that make operation of the system the easiest. Durkin (1994) states that the key to effective interface design is consistency, clarity and control. These three factors will be used as a guide during the development of the user interface.

Consistency refers to the screen format or display. A consistent screen display gives the user a mental model of where information is on the screen. The screens will be designed so that similar information always appears at the same location on different screens. This will make navigation and data input faster and easier for the user.

Clarity refers to the information provided by the expert system. The information must be simple and understandable by the user. The S2A2 will ensure that the information speaks the language of a commander by using doctrinal Army terms. The assessment and explanations will be written in such a manner that the commander has no

doubt whatsoever about the information on the screen. Previous commanders and staff officers will be again used to make sure that the information is clear.

Control refers to the fact that the commander feels that he is in control of the system's operation. To do this starting and exiting the S2A2 will be made easy for the commander. Exit option will be available for use by the commander on every screen. The S2A2 will also do extensive error checking on every piece of data input by the commander to ensure that the data is input in the correct format. A comprehensive help feature will give the commander additional control during the operation of the expert system.

Testing the Expert System

Testing of the S2A2 involves two separate activities. The first is verification and involves testing and debugging the code to determine if the S2A2 behaves as it was intended. The second test involves validating the S2A2 to ensure that it produces the same results as the expert based upon the inputs to the S2A2. Validation ensures that the S2A2 behaves like the real system, the S2.

Verifying the S2A2

Verifying the S2A2 involves determining if the S2A2 behaves as it was intended. In order to verify the S2A2, test cases will be used to check the code of the S2A2. The testing will include going assessing each rule used for each test case. This testing shows

that the code is in fact working properly and the assessment produced is correct. Verifying the S2A2 obviously precedes the validation of the S2A2.

Scenario Used to Verify the S2A2

The scenario used to verify the S2A2 (Figure 4) consisted of six (6) scout teams located on a hilltop observing the east/west movement of 30 T-72 tanks. The terrain used for the verification was at the national training center. The tanks moved along two avenues of approach (AA) with the scout teams observing six (6) NAIs along those AAs. NAIs 1 – 3 were located along the avenue of approach in the north and NAIs 4 – 6 were located along the avenue of approach in the south. Different movement routes of the tanks comprised three distinct COAs. The first COA had all 30 tanks moving along the avenue of approach in the north. The second COA had 15 tanks moving along the avenue of approach in the north and 15 tanks moving along the avenue of approach in the south. The third COA had all 30 tanks moving along the avenue of approach in the south.

Figure 4. Verification Scenario

Rules and rule sets were constructed to determine which COA the enemy was employing. An example of the rules associated with COA1 is as follows. Indicator 1 (I1) was 20 T-72 tanks at NAI 1, I2 was 20 T-72 tanks at NAI 2 and I3 was 20 T-72 tanks at NAI 3. R1 was I1 within 10 minutes with a 90% certainty factor. R2 was I2 within 10 minutes with a 90% certainty factor. R3 was I3 within 10 minutes with a 90% certainty factor and R13 was I1 $\wedge$ I2 within 30 minutes with a 90% certainty factor. Rule set 1 (RS1) was R1 with a 30% certainty factor. RS2 was R2 with a 30% certainty factor. RS3 was R3 with a 30% certainty factor. RS4 was R13 with a 50% certainty factor. RS5 was R1 and R3 with a 50% certainty factor. RS6 was R2 and R3 with a 50% certainty factor. RS7 was R1, R2 and R3 with a 90% certainty factor and RS23 was R7, R8 and R9 with a –90% certainty factor. The complete description of the scenario, rules and objectives of the verification of the S2A2 code is at Appendix B.

Validating the S2A2

Validating the S2A2 will consist of determining if the S2A2 is producing the same assessment as the expert or S2. A more complete validation would involve multiple S2s. Due to limited resources, the assessment of a single expert, the author, was used. The validation will first include running a number of Janus scenarios. A single expert

will develop rules for the S2A2 for each Janus scenario and use the information produced by the scenarios to determine if it behaves like an actual S2 might. Some quantitative rules provide some confidence in the system's behavior.

Purpose of the Validation

Specifically, the validation phase of the experiment will look to answer two questions about the system. Does the S2A2 produce the correct assessment? Is the S2A2 stable? It is important to understand what is meant by each of the two questions and the methodology used to answer each of these questions.

The first question looks to determine if the S2A2 produces a correct assessment. By definition a correct assessment is one in which the S2A2 correctly identifies the COA that the OPFOR is employing in time for the commander to react to that assessment. A commander has little utility for the S2A2 if it produces a correct assessment but that assessment is reported 5 minutes before the OPFOR main body reaches the main defensive belt of the friendly force. For that reason a correct assessment implies that the assessment is also timely.

The second question looks to determine if the S2A2 is stable. Stability means that the assessment does not change, i.e., the S2A2 doesn't produce a correct assessment and then some time later produce another incorrect assessment.

Scenario Used to Validate the S2A2

Although in theory, the cognitive process that intelligence officers use to make assessments is identical at all staff levels, due to limitations the research implemented the validation of the S2A2 at the battalion level. This research or thesis assumes that a battalion has a large complement of intelligence assets and the information produced by those assets is manageable. The large complement of intelligence assets in turn gives the S2A2 some robustness. At the brigade and division level there are many intelligence assets and for a single person, the management of the corresponding data produced by those assets would be very difficult. A commander or single person would also have difficulty controlling a division scenario using Janus which would be the case if the S2A2 validation was implemented at the brigade level versus an attacking division opposing force.

Although the S2A2 has the capability to make assessments on multiple enemy courses of action for any scenario, to limit the scope of the research, one specific mission will be used for the friendly force - a deliberate defense. The number of possible enemy courses of action will also be limited to three for the scenario. Additionally the enemy course of action will be fixed and not dynamic in nature. Once a battle begins the enemy will not be allowed to change courses of action based upon friendly actions.

The specific scenario used to validate the S2A2 consists of a mechanized infantry battalion conducting a deliberate defense against an attacking motorized rifle brigade (MRB) at the United States Army National Training Center. The MRB attacked from the

west to the east. While additional alternative courses of action could have been contrived, all three OPFOR courses of action had the main effort along the northern avenue of approach. COA 1 was a reversed wedge with a first echelon consisting of an armor battalion in the north and a motorized rifle battalion in the south. The second echelon consisted of two motorized rifle battalions along the northern avenue of approach. COA 2 used a "two up and two back formation" with the first echelon consisting of an armor battalion in the north and a motorized rifle battalion in the south. The second echelon consisted of a motorized rifle battalion in the north and a motorized rifle battalion in the south. COA 3 used a "three up and one back formation" with the first echelon consisting of a motorized rifle battalion in the north, an armor battalion in the center and a motorized rifle battalion in the south. The second echelon consisted of a motorized rifle battalion in the north. A graphical representation of the OPFOR courses of action is at Figure 5 below.

Figure 5. Validation Scenario - OPFOR Courses of Action

Multiple friendly force coursed of action could have been created. In this research, the friendly force COA 1 consisted of an armor company in a counter-reconnaissance role forward (west) of the main defensive belt. The main defensive belt consisted of a mechanized company in the north and a mechanized company in the south. An armor company served as the reserve. COA 2 consisted of an armor company and mechanized company in the north, an armor company (+) in the south and a mechanized company (-) as the reserve. COA 3 consisted of an armor company (+) in the north, an armor company and a mechanized company in the south and a mechanized company (-) as the reserve. In all three COAs reconnaissance assets consisting of 10 scout teams, 3 ground surveillance radars and 2 M2A2s (from the division cavalry), were forward of the main defensive belt. Each of the OPFOR COAs was tested against each of the friendly force COAs to get a total of nine runs. A graphical representation of the OPFOR courses of action is at Figure 6 below and a complete description of the validation scenario is at Appendix D.

Figure 6. Validation Scenario - Friendly Force Courses of Action

Validating A Correct Assessment

As mentioned earlier, the commander has the capability to input a threshold value for a correct assessment. Three thresholds were chosen for validation (.6, .7 and .8). Since by definition a correct assessment is timely, a no later than (NLT) time was determined. The NLT time was the last possible moment that the commander could modify his COA to react to an OPFOR COA. As an example, if the friendly force was deployed to defend against OPFOR COA 1 and the OPFOR was attacking using COA 3, then the NLT would be the last possible moment that the commander could modify from COA 1 defense to a defense designed for OPFOR COA 3. The NLT time was determined for all nine runs. In the case where the friendly force was deployed using the same COA as the OPFOR, the NLT was equivalent to the assessment time of the S2A2. Next a time difference was computed using equation 10 to get 9 data points (three of the data points were equivalent to zero) for each threshold value.

$$\text{Time Difference (TD)} = \text{assessment time} - \text{NLT} \tag{10}$$

Each remaining data point will either be positive (timely) or negative (untimely). Using these positive and negative data values, along with the runs test, will determine if the S2A2 produced the correct assessment. The runs test determines if a sequence of data points is random or not random. A non-random result with most or all of the data points being positive will show that the S2A2 produced correct assessments for each of the three

threshold levels. The details of the runs test (Walpole, Myers and Myers, 1998) is as follows:

H_0: Sequence is random.

H_1: Sequence is not random.

$\alpha = 0.1$

Test Statistic: V, the total number of runs.

n_1 = number of positive values

n_2 = number of negative values

v = the total number of runs

Reject H_0 when $P = 2P$ ($V <= v$ when H_0 is true) < 0.1

Validating A Stable Assessment

Over time the S2A2 will produce LBs for each COA. For each of the nine runs the LBs associated with the correct COA will be analyzed. As an example, when the friendly force is executing COA 2 and the OPFOR is executing COA 1 the LBs associated with COA 1 will be analyzed. Each data point is equivalent to the LB for that COA at a given time. For each scenario the S2A2 will report every ten minutes. Once the scenario is complete (10 hours, 20 minutes) there will be 62 data points (620 / 10). Once again the runs test will be used for three threshold values (.6, .7 and .8). Once an S2A2 assessment meets or exceeds the threshold, all observations after that point in time will be analyzed. The threshold value will be subtracted to get either a positive or

negative number. These values along with the runs test will determine if the S2A2 is stable. If the sequence of data points is not random (not fluctuating from a correct assessment) this will show that the S2A2 produced stable assessments for each of the three thresholds levels. The details of the runs test (Walpole, Myers and Myers, 1998) is as follows:

H_0: Sequence is random.

H_1: Sequence is not random.

$\alpha = 0.1$

Test Statistic: V, the total number of runs.

n_1 = number of positive values

n_2 = number of negative values

v = the total number of runs

Reject H_0 when $P = 2P(V <= v \text{ when } H_0 \text{ is true}) < 0.1$

CHAPTER 4

CONDUCT OF THE S2A2 TESTS, RESULTS AND ANALYSIS

Introduction

In this chapter the conduct of the S2A2 verification and validation tests will be discussed. The methodology used for the verification tests and the results of those tests will be described in detail. Finally the validation test results and an analysis of the results will follow.

Verification Test

The purpose of the verification test was to ensure that the logic and code of the S2A2 functions properly. The verification was done incrementally where sets of code were tested separately before conducting a composite test. The specific objectives of the verification test were as follows:

1. Test to ensure that rules are processed properly.
    a. Indicators are being counted properly.
    b. The logic (AND, OR) of a rule works properly.
    c. The rule time window works properly.

2. Test to ensure that rule sets are processed properly.

   a. Only the highest level non-true rule is processed.

   b. Rule set certainty factor arithmetic functions properly.

3. Test to ensure that COAs are processed properly.

   a. All rule sets are processed at each evaluation.

   b. COA certainty factor arithmetic functions properly.

4. Test to ensure the reporting works properly.

   a. Reports are generated according to the user specified interval.

   b. COAs are identified as being adopted by the OPFOR if the level of belief meets or exceeds the user specified threshold.

   c. COAs are identified as not being adopted by the OPFOR if the level of belief is less than the user specified threshold.

   d. All COAs are reported on.

Rule Tests

The tests to ensure that rules are processed properly focused on three issues: are indicators being counted properly, does the rule logic work as planned and does the time window for a rule function correctly. In order to test these three issues, simple rules were defined for the scenario described in Appendix B, Verification Scenarios. The rules contained only one indicator in its definition. Separate rules were also created so that the

indicator threshold count was both less than (for COAs North and South) and greater than (for COA Split) the actual equipment count in the scenario. Lastly, rules were created for equipment types that were not in the scenario. The S2A2 was then run for these simple rules and the results were checked against the known events of the scenario. If any evaluation proved to be incorrect, the code was debugged by using a feature in PowerModel that allows the programmer to step through each line of code in the program. This debugging procedure was used for all verification tests.

To test the rule logic, rules were created that used all combinations of the logical AND and logical OR operands. The S2A2 was again run against the verification scenario and checked to see if the operands functioned properly. To test the rule's time window rules were created that had very short time windows. These short time windows were created so that the rule would not become true. Additionally rules were created that had reasonable time windows so that, when the scenario was run, the rule would become true. The S2A2 was again run using these rules and checked for correct results. Once it was determined that the rules processed properly, tests were conducted to check the functionality of rule sets.

Rule Set Tests

The rule set tests focused on two issues: testing to see if the rule set processed only the highest level non-true rule and testing the rule set certainty factor arithmetic. In order to test the rule set to see if the highest level non-true rule was processed, a rule set

was created that contained two rules. The first rule was one that would never become true and the second rule was one that should be evaluated as true based upon the events of the verification scenarios. The S2A2 was run in order to see if the second rule of the rule set was ever evaluated. The rule was in fact never evaluated. Next a rule set was created that contained two rules where the first rule was one that should become true after the second rule became true. The test showed that, although the second rule would have become true first, it was not evaluated as true first because it was not processed until after the first rule became true. The S2A2 was run to see if the first rule was in fact processed before the second rule. This allowed for the checking of the sequencing feature in the S2A2. Lastly a rule set was created that contained two rules where the first rule became true before the second rule became true. The rule set did in fact process the first rule and then the second rule.

The testing of the rule set certainty factor arithmetic was just a matter of checking to see if the formulas described in chapter 3 worked properly. Recall that the S2A2 uses conjunctive rules and that the general form of a conjunctive rule is: IF E_1 AND E_2 AND . . . E_i THEN H CF(Rule). The formula for calculating a level of belief for a conjunctive rule from equation 2 is LB(H, E_1 AND E_2 AND . . . E_i) = min {CF(E_i)}*CF(Rule). Essentially the level of belief for a rule set is the minimum certainty factor of the rules that make up the rule set multiplied by the certainty factor of the rule set. This test compared the rule set levels of belief produced by the S2A2 with manual computations for the levels of belief for the rule sets.

COA Tests

The COA verification tests focused on two issues: testing to ensure all rule sets were processed at each evaluation and testing to see if the COA certainty factor arithmetic functioned properly. To test the COAs to ensure that all rule sets were processed at each evaluation, three rule sets were created, each containing one rule. Simple scenarios were created so that a combination of the rule sets would become true at different reporting times. The reports produced by the S2A2 allowed for the checking of the COA's evaluation of rule sets. The reports were then cross checked with the know results of the scenario. The S2A2 processed all rule sets as anticipated during each evaluation.

The COA certainty factor arithmetic test was very similar to rule set certainty factor arithmetic test. Rules and rule sets were created that had both positive and negative certainty factors. This test compared the COA's levels of belief produced by the S2A2 with manual computations for the levels of belief for the COAs using formulas 4 - 9. The COA tests showed that the S2A2 processed COA certainty factor arithmetic as expected.

Reporting Tests

The last incremental tests were the reporting tests. The first test was conducted to verify that S2A2 reports were generated according to the user specified interval. The

second test was conducted to verify that all COAs were identified in the report as either being adopted by the OPFOR if they met or exceed the user specified threshold or not being adopted otherwise. To implement these tests, several different time intervals were input into the S2A2 and the resulting reports were checked against the specified time interval. At first the reporting was off by, in some cases, one minute. The code was debugged and the test was rerun. Finally, the levels of belief for each COA were compared against the defined confidence threshold value to see if S2A2 correctly processed the levels of belief properly. The S2A2 had no problems with the reporting of adopted and not adopted COAs.

Composite Test

After all the incremental tests were complete a composite test was done using the scenario and rules defined in Appendix B, Verification Scenarios. Indicators, rules, rule sets and COAs were created and run against three Janus scenarios that related to a distinctly different OPFOR COA. The reporting interval was set to four minutes and the confidence threshold was set to 60%. The output of the S2A2 scenario runs is at Appendix C, S2A2 Verification Test Output. Each of the three scenario runs will be discussed.

COA 1

COA 1 was run for 32 minutes, the time it took the tanks to move from their starting position to their final position. At the first reporting time, 241104Z, no rules or rule sets became true. During this time period the tanks started moving east along AA North from the assembly area.

At the next reporting time, 241108Z, rule set 1 became true as did several other rules. Rule set 1 was the detection of 20 tanks at NAI 1. The overall level of belief for COA North was 27%.

At the 241112Z reporting time no additional rules became true for COA North but rule set 8 became true for COA Split and its level of belief was 13%. This was the detection of 10 tanks at NAIs 1 and 2. It is interesting that COA North's Rule Set 4, the detection of 20 tanks at NAIs 1 and 2, did not become true. This is because the overall threshold count was not met for the tanks at NAI 2.

At the next reporting time, 241116Z, the tanks have moved completely through NAIs 1, 2 and 3. All rule sets became true for COA North except rule set 23. This rule set was the detection of 10 tanks at NAIs 4, 5 and 6 (along AA South). Rule set 23 had a certainty factor of –90% and is used to decrease the level of belief for COA North if any of the other two COAs were being adopted. The rule sets associated with the tanks moving along AA North became true for COA Split at this reporting time. Rule set 24 (the detection of 10 tanks at NAIs 1, 2 and 3) decrements the overall level of belief for the COA South. The level of belief for COA North was 98% and the S2A2 correctly

reported that the COA was being adopted by the OPFOR. Also at this reporting time COA Split had a level of belief of –70% and COA South's was –81%. During the remaining reporting times there were no additional detections and the output remained the same.

COA 2

COA 2 was also run for 32 minutes, the time it took the tanks to move from their starting position to their final position. Like COA 1, no rules or rule sets became true at the first reporting time (241104Z). During this time period, the tanks started their movement east from the assembly area and along AAs North and South.

At the 241108Z reporting time there still were no true rule sets. Rule 4 and rule 7 became true. These rules corresponded to the movement of 10 tanks at NAIs 1 and 4. At this time the level of belief for each COA is still zero.

At the 241112Z reporting time, rule set 11, the detection of 10 tanks at NAIs 4 and 5 became true. The level of belief for COA Split was 13% but was still below the threshold of 60% and, therefore, the S2A2 did not report the adoption of the COA.

The 241116Z report produced a 0% level of belief for COA North, a 69% level of belief for COA Split and a –81% level of belief for COA South. At this point in the scenario, the 15 tanks moving along AA North passed through NAIs 1, 2 and 3 and were properly detected. The 15 tanks moving along AA South passed through NAIs 4 and 5

but not 6. The detection of the tanks moving through NAIs 1 - 3 triggered rule set 23 in COA South and caused the level of belief of the COA to be decremented.

The tanks completely moved through all NAIs at the 241120Z reporting time. All rule sets with a positive certainty factor became true for COA Split and the resulting level of belief was 87%. Rule set 23 became true for COA North, which caused the level of belief for the COA to be decrement much like rule set 24 for COA South. The overall level of belief for COA Split is 87% and –81% for COAs North and South. During the remaining reporting times there were no additional detections and the output remained the same.

COA 3

COA 3 was run for 36 minutes, the time it took the tanks to move from their starting position to their final position. At the first reporting time (241104Z) the tanks started moving east along AA South from the assembly area. Rule set 16 became true which was the detection of 20 tanks at NAI 4 as well as all the other rules associated with the detection of tanks at NAI 4. The overall level of belief for AA South was 27% but still well below the 60% threshold.

At the next reporting time, 241108Z, there are no additional detections from the previous report. At the 241112Z report time rule sets 17, 19, 11 and 26 became true. The tanks were detected moving through NAIs 4 and 5. Rule set 11 detected the movement of 10 more tanks through NAIs 4 and 5 which incremented the level of belief for COA Split,

but rule set 26, the detection of 20 or more tanks through those same NAIs decrements the level of belief for COA Split. The levels of belief for COA North, COA Split and COA South are 0%, –36% and 70% respectively. The S2A2 correctly reported that the OPFOR adopted COA South.

At the 241116Z reporting time the tanks have moved completely through NAIs 4, 5 and 6. All rule sets became true for COA South except rule set 24. This rule set was the detection of 10 tanks at NAIs 1, 2 and 3 (along AA North). This rule set has a certainty factor of –90% and was used to decrease the level of belief for COA South if any of the other two COAs were being adopted. The level of belief for COA South was 98% and the S2A2 correctly reported at the COA was adopted by the OPFOR. Also, at this reporting time, COA Split had a level of belief of –70% because the rule sets associated with the tanks moving along AA South became true. COA North's level of belief was -81%. During the remaining reporting times there were no additional detections and the output remained the same.

All three verification runs showed that the S2A2 operated as intended. Once the S2A2 was verififed, the next step was to run the validation test.

Validation Test

The purpose of the validation test was to determine if the S2A2 produced the same assessment as the expert or S2. Specifically, the validation test measured the ability of the S2A2 to produce correct and stable assessments. A correct assessment is one in

which the S2A2 correctly identifies the COA that the OPFOR is employing in time for the commander to react to that assessment. The S2A2 is stable if, over time, the assessment that it produces does not fluctuate between a correct and incorrect COA. For each of these two tasks a variety of threshold values (which the commander inputs into the S2A2) is used. The S2A2 uses the threshold value to determine the minimum level of belief that a COA must attain in order for S2A2 to report that the OPFOR is adopting a particular COA. The three thresholds used for were validation .6, .7 and .8.

Scenario Used to Validate the S2A2

The scenarios used to validate the S2A2 consisted of an OPFOR motorized rifle brigade (MRB) attacking a mechanized infantry battalion which is in a deliberate defense (Appendix D, Validation Scenario). Initially, three OPFOR COAs were developed. After the OPFOR COAs were developed, a friendly force COA was created to counter each OPFOR COA. Each OPFOR COA was then run in the Janus simulation against each friendly force COA. This brought the total number of runs to nine.

Validating a Correct Assessment

After the nine runs were completed using the Janus simulation, data were collected that measured the timeliness of a correct assessment for each run. The data represented a sequence of nine points. Non-parametric statistics, specifically the runs test, was used to determine if the data sequence appeared in a random or non-random

order. A conclusion was made that the S2A2 produced correct results if the data appeared to be non-random.

The first task after the scenario runs were complete was to determine a no later than time (NLT) for each run. The NLT time was the last possible moment that the commander could modify his COA to counter the OPFOR's COA. As an example, the OPFOR was deploying using COA 1 and the commander deployed his force on the incorrect assumption that the OPFOR was using COA 3. The commander would want to modify his plan so that his forces were deployed according to the correct COA, in this case COA 1. The NLT was calculated by subtracting doctrinal movement times from the time that the OPFOR's main body makes contact with the friendly force's main defensive belt. In the case when the commander deployed his forces correctly, the NLT is equivalent to the assessment. Table 3 summarizes the NLT for each of the nine runs.

Table 3

Scenario Run No Later Than Times

OPFOR COA	Friendly COA	NLT Time	=	Contact Time	-	Movement Time
1	1	AT		NA		NA
1	2	2230		2330		60 min
1	3	2100		2200		60 min
2	1	0010		0110		60 min
2	2	AT		NA		NA
2	3	2215		2300		45 min
3	1	2245		2345		60 min
3	2	2215		2315		60 min
3	3	AT		NA		NA

Next, a time difference was computed using the equation 10, Time Difference (TD) = assessment time (AT) – NLT. The time difference was computed for each of the nine runs using the three COA levels of belief threshold values (.6, .7 and .8). The result was nine data points (three of which were equal to zero) for each COA level of belief threshold value. The time difference data value essentially represents the amount of lead-time that a commander has to modify his COA based upon the OPFOR COA. Tables 4 – 6 lists the time difference for the nine scenario runs based upon the COA level of belief threshold value.

Table 4

Time Difference at the .60 Threshold Value

OPFOR COA	Friendly COA	Time Difference (TD) =	Assessment Time (AT) -	NLT Time
1	1	0	2130	2130
1	2	-10	2220	2230
1	3	-10	2050	2100
2	1	-20	2350	0010
2	2	0	2340	2340
2	3	-95	2040	2215
3	1	-15	2230	2245
3	2	-55	2120	2215
3	3	0	2040	2040

Table 5

Time Difference at the .70 Threshold Value

OPFOR COA	Friendly COA	Time Difference (TD) =	Assessment Time (AT) -	NLT Time
1	1	0	2130	2130
1	2	-10	2220	2230
1	3	-10	2050	2100
2	1	-20	2350	0010
2	2	0	2340	2340
2	3	-95	2040	2215
3	1	-15	2230	2245
3	2	-55	2120	2215
3	3	0	2120	2120

Table 6

Time Difference at the .80 Threshold Value

OPFOR COA	Friendly COA	Time Difference (TD)	=	Assessment Time (AT)	-	NLT Time
1	1	0		2230		2230
1	2	150		0100		2230
1	3	60		2200		2100
2	1	-20		2350		0010
2	2	0		0130		0130
2	3	-55		2120		2215
3	1	25		2310		2245
3	2	-45		2130		2215
3	3	0		2120		2120

Conduct of the Runs Test

The runs test was used to determine if the S2A2 produced correct results at each COA level of belief threshold value. The runs test determines if a subsequence of one or more identical symbols representing a common property of the data, based upon the order in which sample observations are obtained, were drawn at random (Walpole, Myers and Myers, 1998). In the test to validate the correct assessments of the S2A2, a positive time difference value is represented by the symbol '+' and a negative time difference value is represented by the symbol '-'. The data values with a time difference equal to zero are eliminated from the sequence. If the sequence of data points that represent the amount of lead-time that a commander has to modify his plan is in a non random order, then the S2A2 is producing assessments that are timely. This is because the symbols that

represent the time difference (lead-time) are primarily negative (timely). If the sequence is in a random order, then the S2A2 is producing assessments that are not timely.

The null and alternative hypotheses for the runs test at the .60 COA level of belief threshold is as follows.

H_0: Sequence is random.

H_1: Sequence is not random.

$\alpha = 0.1$, level of significance

Test Statistic: V, the total number of runs.

Computations: Using the time difference data values from Table 4 with the positive and negative time difference values are represented by the symbols '+' and '-' respectively, the following sequence is obtained:

- - - - - -

for which the number of positive values, $n_1 = 0$, the number of negative values, $n_2 = 6$, and the of runs, $v = 1$. Using statistical tables that apply to the runs test (Walpole, Myers and Myers, 1998), the computed P-value is $P = P$ ($V <= v$ when H_0 is true) = 0. Since $0 < 0.1$, the hypothesis that the sequence of data points that represent the time difference is random is rejected and conclude that with a 90% confidence level the sequence is not random. Therefore, the S2A2 did produce correct and timely assessments at the .60 COA level of belief threshold.

The null and alternative hypotheses for the runs test at the .70 COA level of belief threshold is as follows.

H_0: Sequence is random.

H_1: Sequence is not random.

$\alpha = 0.1$, level of significance

Test Statistic: V, the total number of runs.

Computations: Using the time difference data values from Table 5 with the positive and negative time difference values are represented by the symbols '+' and '-' respectively, the following sequence is obtained:

- - - - - -

for which the number of positive values, $n_1 = 0$, the number of negative values, $n_2 = 6$, and the of runs, $v = 1$. Using statistical tables that apply to the runs test, the computed P-value is $P = P$ ($V <= v$ when H_0 is true) = 0. Since $0 < 0.1$, the hypothesis that the sequence of data points that represent the time difference is random is rejected and conclude that with a 90% confidence level the sequence is not random. Therefore, the S2A2 did produce correct and timely assessments at the .70 COA level of belief threshold.

The null and alternative hypotheses for the runs test at the .80 COA level of belief threshold is as follows.

H_0: Sequence is random.

H_1: Sequence is not random.

$\alpha = 0.1$, level of significance

Test Statistic: V, the total number of runs.

Computations: Using the time difference data values from Table 6 with the positive and negative time difference values are represented by the symbols '+' and '-' respectively, the following sequence is obtained:

+ + - - + -

for which the number of positive values, $n_1 = 3$, the number of negative values, $n_2 = 3$, and the of runs, $v = 4$. Using statistical tables that apply to the runs test, the computed P-value is $P = P\ (V <= v \text{ when } H_0 \text{ is true}) = .70$. Since $.70 > 0.1$, we fail to reject the hypothesis that the sequence of data points that represent the time difference is random and conclude that with a 90% confidence level the sequence is random. Therefore, the S2A2 did not produce correct and timely assessments at the .80 COA level of belief threshold.

Analysis of the Runs Test

The S2A2 produced correct and timely assessments at the .6 and .7 levels of belief but at the .8 level of belief, the assessments were not timely. There are several potential reasons why the assessments were not timely at the .8 level of belief. Some of those reasons could be that the reconnaissance assets did not detect the OPFOR, incorrect certainty factors were used and indicators were incorrect.

The S2A2 may not produce timely assessments at the .8 level of belief because the reconnaissance assets did not detect all OPFOR units, namely the second echelon. As a result, the level of belief for the OPFOR COA did not exceed the .8 threshold. This

occurred for several reasons, primarily because from the assets' current positions, they could not observe the movement of the OPFOR's second echelon. This is not only a challenge with the S2A2, but also with the real world placement of intelligence assets. An S2 has a limited number of intelligence assets and must prioritize their use in order to gather as much information about the OPFOR as possible. It is probably unlikely that all the battalion reconnaissance assets could detect all OPFOR movements. Therefore, careful planning is required to detect as much as possible of the most important information.

Another reason associated with reconnaissance assets that potentially produce untimely assessments is that the reconnaissance assets were killed during the battle. Although scouts are trained to use stealth when either moving or stationary, there are times when they will unexpectedly come into contact with an OPFOR element. In simulation, just like in the real world, scouts sometimes die. The observation point could be a perfect location to detect the OPFOR, but if scouts do not get to that location or "hide" once at the location, then the probability that the information will be collected is very low.

Incorrect certainty factors associated with rule sets could produce untimely assessments. Conversely, a reporting certainty factor threshold could be set to high. If events occur that would lead an S2 to conclude that the OPFOR is adopting a COA, then the certainty factors associated with rule sets and the calculated COA level of belief should exceed the reporting certainty factor threshold. Also, if all rule sets for a particular

COA have become true, then the level of belief for the COA should exceed the reporting certainty factor threshold. If it does not then the user or commander probably has too high an expectation for the level of belief that a COA should attain.

The last potential explanation for untimely assessments is that the indicators that were used were incorrect. This occurs when the threshold level for an indicator is set too high. As an example, a tank battalion has 31 tanks and the threshold level for the indicator is set to 31. If prior to moving through the NAI associated with the indicator, the tank battalion makes contact with a friendly force unit and losses 4 tanks, then the indicator will not meet or exceed the threshold that was defined by the user. Again, the S2 must plan carefully when developing indicators to ensure that the detection of OPFOR equipment exceeds the count threshold.

Validating A Stable Assessment

After the Janus simulation completed the nine data runs and the S2A2 was run, data were collected that measured the levels of belief for each COA based upon a reporting time of 10 minutes. For each of the nine runs, the levels of belief associated with the actual OPFOR COA were captured. Each data point is equivalent to the level of belief for that COA at a given time. There were approximately a total of 60 data points for each of the nine scenario runs (10 minute reporting interval* 60 minutes per hour / 10 hours). Once again the runs test was used for three threshold values (.6, .7 and .8).

Conduct of the Runs Test

The runs test was used to determine if the S2A2's assessments are stable. Once an S2A2 assessment met or exceeded the threshold value for the actual implemented OPFOR COA, all observations after that point were used to analyze stability. The threshold value was then subtracted from the S2A2 produced COA level of belief. This resulted in either a positive or negative number. The data values used in the S2A2 stability validation test is at Appendix E, S2A2 Stability Data Values. The runs test determines if a subsequence of one or more identical symbols representing a common property of the data, based upon the order in which sample observations are obtained, were drawn at random. In the test to validate the stability S2A2 assessments, a positive level of belief value is represented by the symbol '+' and a negative time level of belief value is represented by the symbol '-'. The data values with a level of belief equal to zero are eliminated from the sequence. If the sequence of data points that represent the stability of an S2A2 assessment is in a non-random order (not fluctuating from a correct assessment), then the S2A2 is producing stable assessments. This is because the symbols that represent the difference from the COA level of belief threshold value are primarily positive and are not fluctuating. If the sequence is in a random order, then the S2A2 is producing unstable assessments.

The null and alternative hypotheses for the runs test at the .60 COA level of belief threshold is as follows.

H_0: Sequence is random.

H_1: Sequence is not random.

$\alpha = 0.1$, level of significance

Test Statistic: V, the total number of runs.

Computations: Using the COA level of belief threshold difference data values from Appendix F with the positive and negative time difference values are represented by the symbols '+' and '-' respectively, the number of positive values, $n_1 = 39$, the number of negative values, $n_2 = 0$, and the number of runs, $v = 1$. Using statistical tables that apply to the runs test, the computed P-value is $P = 2 * P$ ($V <= v$ when H_0 is true) $= 2 * 0 = 0$. Since $0 < 0.1$, the hypothesis that the sequence of data points that represent the difference between the COA level of belief and the threshold is random is rejected and conclude that with a 90% confidence level the sequence is not random. Therefore the S2A2 produces stable assessments at the .60 COA level of belief threshold.

The null and alternative hypotheses for the runs test at the .70 COA level of belief threshold is as follows.

H_0: Sequence is random.

H_1: Sequence is not random.

$\alpha = 0.1$, level of significance

Test Statistic: V, the total number of runs.

Computations: Using the COA level of belief threshold difference data values from Appendix F with the positive and negative time difference values are represented by the symbols '+' and '-' respectively, the number of positive values, $n_1 = 36$ the number of

negative values, $n_2 = 0$, and the number of runs, $v = 1$. Using statistical tables that apply to the runs test, the computed P-value is $P = 2 * P (V <= v \text{ when } H_0 \text{ is true}) = 2 * 0 = 0$. Since $0 < 0.1$, the hypothesis that the sequence of data points that represent the difference between the COA level of belief and the threshold is random is rejected and conclude that with a 90% confidence level the sequence is not random. Therefore the S2A2 produces stable assessments at the .70 COA level of belief threshold.

The null and alternative hypotheses for the runs test at the .80 COA level of belief threshold is as follows.

H_0: Sequence is random.

H_1: Sequence is not random.

$\alpha = 0.1$, level of significance

Test Statistic: V, the total number of runs.

Computations: Using the COA level of belief threshold difference data values from Appendix F with the positive and negative time difference values are represented by the symbols '+' and '-' respectively, the number of positive values, $n_1 = 38$, the number of negative values, $n_2 = 0$, and the number of runs, $v = 6$. Using statistical tables that apply to the runs test, the computed P-value is $P = 2 * P$ ($V <= v$ when H_0 is true) $= 2* 0 = 0$. Since $0 < 0.1$, the hypothesis that the sequence of data points that represent the difference between the COA level of belief and the threshold is random is rejected and conclude that with a 90% confidence level the sequence is not random. Therefore the S2A2 produces stable assessments at the .80 COA level of belief threshold.

Analysis of the Runs Test

The S2A2 produced stable assessments at all levels of belief. Other rule sets could have produced unstable assessments. An unstable assessment is not at all unlike what occurs during a real battle. In the real world a S2 makes an assessment based upon all available information at that time. Later additional information may be obtained that

could cause an S2 to change his original assessment. Commanders realize that this is a cost of warfighting. If a commander had "perfect information" then the need for an S2's analysis would be minimal.

CHAPTER 5

CONCLUSIONS, LESSONS LEARNED AND SUGGESTED FUTURE RESEARCH

This purpose of this research was to address the potential to enhance decision-making abilities using artificial intelligence techniques to gather data and information from combat simulation systems to allow decision-makers to train in complete isolation. Quite often U.S. Army commanders train with their entire staff using computer simulation. This research focused specifically on replicating the functions of an intelligence officer to analyze battlefield information and make an assessment based upon that information. A literature review revealed that while there are many systems that assist a commander in the decision-making process, there currently is no system that replicates some or all of the functions of a staff officer. The goal was therefore to develop an application that could be used in the Janus constructive simulation to represent some of the functions of an intelligence officer (S2). The methods used by an S2 to analyze information as outlined in current Army doctrine provided a methodology for the development of the application. To demonstrate the usefulness of the methodology, this research developed an expert system shell that allows an S2 to input indicators, rules and rule sets specific to particular enemy courses of action prior to the

running of a Janus simulation. Additionally, the research methodology introduced a testing strategy to determine if the results produced by the expert system were comparable to the results of an actual S2.

Conclusion

The S2A2 was able to represent the cognitive process used by an S2 when making an assessment based upon combat information received from a Janus computer simulation. The S2A2 currently only has the capability to operate in a Janus simulation and cannot be used as a stand-alone system. Like any computer program, garbage in results in garbage out. No matter how good the information is, if the S2 does not use that information properly then it is useless. If the rules and rule sets are not broad enough to assess potential OPFOR COAs, then the assessment that the S2A2 produces will have little value to a commander. Likewise, while the cognitive process that an S2 uses to make an assessment can be without flaw, if the information to make that assessment is unavailable, then the reliability of that assessment can be at best questionable. Since the ability of the S2A2 to make an accurate assessment is dependent on information, care must be taken to collect that information. The plan used to place intelligence collection assets on the battlefield, referred to as the collection plan, must be completely thought through with the anticipated enemy courses of action in mind.

Lessons Learned

During the testing of the S2A2 it became apparent that there was at least one limitation to the S2A2. This limitation was in the definition of an indicator. An indicator becomes true when the equipment count meets or exceeds the user-defined threshold count. There is only an upper limit and not a lower limit to the threshold count, i.e., and not a range of count values. There are cases when an indicator will become true and a rule becomes true when in fact it should not be true. As an example, a tank company has 10 tanks and the threshold level for the indicator associated with the detection of the tank company is set to 8. If a tank battalion (31 tanks) is detected then the indicator will become true and the rule will conclude the detection of a tank company. In fact a tank battalion was actually observed. This limitation can easily be fixed by providing for a logical not operand. A logical not operand in use in a rule would be in the form of: (10 tanks at NAI 1) AND (NOT 16 tanks at NAI 1). This rule would become true when between 10 and 15 tanks were observed at NAI 1.

Another lesson learned is that rules and rule sets must be constructed to distinguish between courses of action. Now while there are many cases where an event could add some level of belief to multiple courses of action, it is important to distinguish between courses of action so that this happens only when intended. This is tied to the previous lesson learned. The inability of the S2A2 to provide an equipment threshold count range resulted in an increase to the levels of belief for multiple courses of action, even though the particular event should have only increased the level of belief for one

COA. Similarly, many times different units may have the same type of equipment, it is important to distinguish between the units with the same type of equipment so not to make an incorrect assessment.

Lastly, during the validation of the S2A2 only one replication of each scenario was used. This was because of the author's unfamiliarity with some of the features of the Janus simulation. A more comprehensive validation of the S2A2 would have had more replications of the scenarios and thus provided a larger sample size for the analysis of correct and stable assessment.

Future Research

There is a tremendous amount of future research that could improve the functionality of the S2A2, as well as enable decision-makers to train in complete isolation. Additional staff officer agents could be developed to allow a commander to train in complete isolation.

Improving the S2A2

The S2A2 requires that a user input indicators, rules and rule sets in order for it to analyze information to determine which COA the enemy is employing. Rules and rule sets contain certainty factors that are used to provide a level of belief for a hypothesis. Most experienced S2s can very rapidly develop those rules, rule sets and certainty factors based upon past experiences. The inexperienced S2 has very little to rely on when

developing rules, rule sets and certainty factors. The development and validation of rules, rule sets and certainty factors are an obvious extension of this work. Having a template that lists which types of rules and certainty factors to use in certain situations would be indispensable to an S2.

Another way to improve the functionality of the S2A2 is to recommend a report certainty factor threshold. The S2A2 currently requires the user (commander or S2) input the value. As previously mentioned, there are times when a commander may have too high an expectation for a COA level of belief. As a result the S2A2 may never produce a correct assessment, or for that matter, any assessment. An added feature of the S2A2 could be the sensitivity analysis of each COA in order to determine the "correct" report certainty factor threshold.

This study used one scenario and one expert to validate the results of the S2A2. A more complete and through validation of the S2A2 could be conducted. This validation could use multiple scenarios or missions such as an attack in zone, movement to contact or raid. In conjunction with multiple scenarios, a sensitivity analysis of the threshold values used during the validation of correct and stable assessment would provide a more thorough validation. The validation could also use multiple S2s as a factor and test to determine if the results produced by the S2A2 are the same for different S2s. This type of validation would give the S2A2 more validity and credibility. Additionally, the study did not attempt to accredit the S2A2. The validation of multiple S2s could serve as an official accreditation of the S2A2.

While this study used guidelines (consistent, clear and user control) for the development of the user interface, there was little additional research into this area. The majority of effort for this study was on the development of the theory and functionality of the S2A2. Future research could attempt to analyze the user interface more closely in order to determine the best possible interface so that commanders can use the S2A2 as efficiently as possible.

The S2A2 as an Autonomous Agent

To make the S2A2 completely autonomous would require the transitioning of the S2A2 from an expert system shell to an expert system. The S2A2 currently requires an S2 to conduct intelligence preparation of the battlefield (IPB) before the simulation and then input rules into the S2A2. The first step towards the S2A2 as an autonomous agent would be the automation of the IPB process. This would require the development of tools that could analyze the terrain (the maps in Janus). This tool at a minimum should be able to determine possible avenues of approach and possible defensive locations based upon the type of opposing force. The tool should also be able to integrate the degradation of terrain based upon the current or recent significant weather.

The development of a tool to analyze the terrain would allow for the development of the next piece of the autonomous agent. That piece would have to analyze the OPFOR. It would require an extensive knowledge base that contains such information as OPFOR tactics, weapons and equipment. The OPFOR tactics would have to use the

results of the terrain analysis to determine possible OPFOR COAs. This would not be a trivial task since there are hundreds of different opposing forces with different tactics, weapons and equipment. The development of the COAs would complete the IPB phase. Once the autonomous agent has developed possible OPFOR COAs, the last piece would be to develop the rules associated with each COA. This basically would be automating what the S2 must now do in order to make the S2A2 work.

Other Staff Officer Agents

The S2 is just one of the staff officers that a commander has to assist him with his duties during a battle. To allow a commander to train in complete isolation would require the development of agents for the personnel officer (S1), training and planning officer (S3) and the logistics officer (S4). Developing agents for these staff officers will be more challenging than the development of the S2A2 because there is not a formal methodology that outlines the cognitive processes for these staff officers. The knowledge acquisition portion of this task would be the key to success.

The S2A2 does have some extendibility with regard to the development of an S3 agent. During a battle the S3 primarily is concerned with the status of friendly force units. The S2A2's current structure allows for the collection of this type of information. In fact, they way an S2 thinks about the opposing force mirrors the way an S3 thinks about the friendly force. While the goal of the S3 is not to determine the friendly force's course of action, it may be to determine a better course of action to defeat the opposing

force. The structure of the S2A2 could be used to replicate the cognitive processes of an S3 when determining the appropriate changes to friendly force task organization or mission based upon the status of friendly force units.

APPENDIX A

S2A2 DEVELOPMENT

Introduction

The development of the S2A2 is the heart of this thesis. Once it was determined to implement the S2A2 as an expert system shell there were four major issues that needed to be resolved. Those issues were how to design the graphical user interfaces (GUI), how to integrate the S2A2 within SIFT/ISRA, how to represent the logic used by an S2 in making an assessment in the S2A2 and how the S2A2 should process data. This appendix discusses those issues, which really encompass the entire development of the S2A2. Each S2A2 graphical user interface (GUI) will be presented and discussed as well as the reasoning for the development of some of the S2A2 features within the GUI. Additionally, inputting information into the S2A2 using each GUI will be discussed.

Design of the Graphical User Interfaces

The author made all GUIs decisions (design, development and implementation) with the input of other key individuals such as previous commanders and programming specialists. It was previously mentioned that the key to effective interface design is consistency, clarity and control. These three factors were used as a guide during the development of the user interface. Since the first key is consistency and the S2A2 is integrated within SIFT/ISRA, the general format for the GUIs followed the same format as SIFT/ISRA. Screens were designed so that similar information always appeared at the same location on different screens.

Clarity refers to the information provided by the S2A2. To ensure information was simple and understandable by the user, doctrinal Army terms were used. Finally, control refers to the fact that the user feels that he is in control of the system's operation. Exit options are available for the user on every screen. To ensure that the data is input in the correct format, extensive error checking is done on every piece of data input by the user. Comprehensive help features gives the user additional control during the operation of the S2A2.

Integration of the S2A2 into SIFT/ISRA

The integration of the S2A2 into SIFT/ISRA was not a difficult task. As you recall, ISRA is the Intelligent Simulation Reporting Agent and its primary purpose is to read data from the Janus post-processing files. Post-processing files are files that Janus uses to store records of events as they occur during the simulation. SIFT is the Simulation Information Filtering Tool. Its purpose is filter information from a Janus simulation based upon a user's set of information requirements. ISRA was the mechanism that allowed SIFT to interact with the Janus simulation. It provided the means to gather data. SIFT took the data that was provided from ISRA and then filtered that data based upon information that was deemed critical by the commander. That critical information was in the form of CCIR (Commander's Critical Information Requirements). In order for the S2A2 to function properly it needed to be able to read Janus data, filter the data and process the data. The integration of the S2A2 into

SIFT/ISRA was therefore just a matter of adding a feature that processes the data and is able to interact with the data reading capability of ISRA and the filtering capability of SIFT. The feature to process the data is the S2A2.

ISRA Setup

Once the SIFT/ISRA/S2A2 executable file is run, the first GUI that will be displayed is the ISRA Main Menu and is shown in Figure 7.

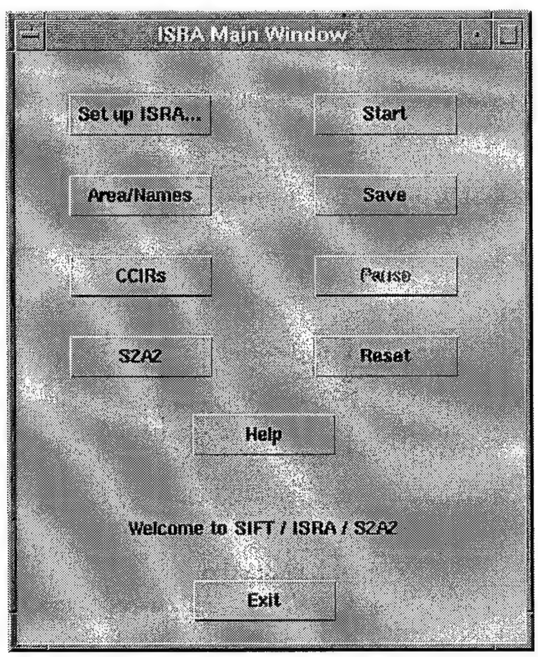

Figure 7. ISRA Main Window

Initially all buttons will be deactivated except the button labeled "Set up ISRA…" because, prior to running the S2A2, the user must interact with ISRA and tell ISRA where the data is located. When the "Set up ISRA…" button is activated the GUI at Figure 8 appears.

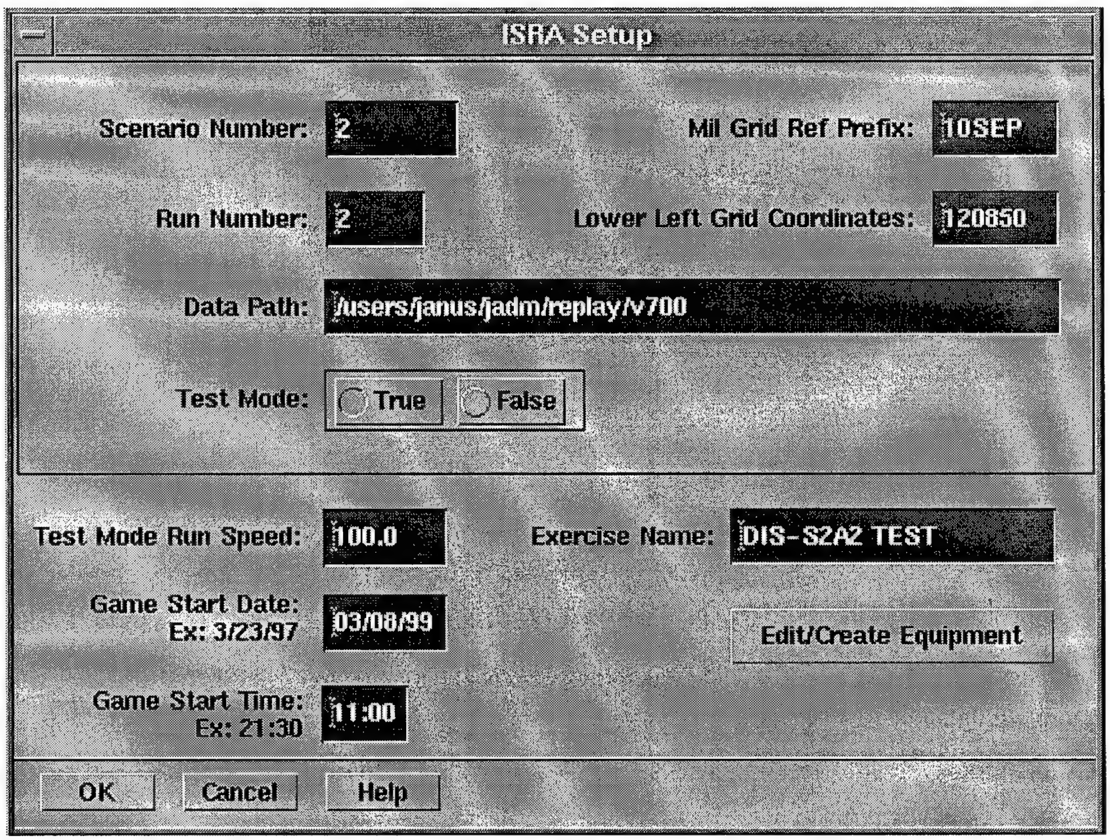

Figure 8. ISRA Setup

In order for ISRA to read the appropriate Janus post processing files the user first must input the name of the Janus scenario and the location of the scenario data. The scenario number and run number fields in the "ISRA Setup" GUI correspond to the Janus scenario and run data. The data path is the location of the Janus post processing files. One step that is not implicitly defined in the "ISRA Setup" GUI must be accomplished before running the S2A2. The user must create a Janus FORCEXXX.LIS file, where XXX is the scenario number, using the Janus simulation software. This procedure is outlined in the Version 7 Janus Software User's Manual, 3.1.7 Print Scenario Forces (Option PP). ISRA uses this file to read unit information about the forces in the scenario. When the FORCEXXX.LIS file is created, the Janus simulation software will place this file in the user's directory (/users/Janus/jadm). When the user inputs the path to the post-processing data files ISRA looks for the FORCEXXX.LIS file two levels up from the specified data path. Using the data path that is shown in Figure 8, /users/Janus/jadm/replay/v700, ISRA would expect to see a file named FORCE002.LIS in the /users/Janus/jadm directory.

The "Mil Grid Reference Prefix" and "Lower Left Grid Coordinates" fields of the "ISRA Setup" GUI correspond to the grid coordinate system that is used in the Janus scenario. It is necessary to input this information so that ISRA can translate the coordinate data in the Janus post-processing files (stored as a Cartesian coordinate system) into a military grid coordinate system with the correct grid square prefixes. The "Test Mode" buttons are used to set up ISRA for the appropriate Janus simulation run.

When the “Test Mode” is set to “True”, SIFT is reading data from a completed scenario. When the “Test Mode” is set to “False” SIFT is operating in a real time mode. The test mode run speed can be set to have ISRA process data faster or slower than real time when the “Test Mode” is set to “True”. Lastly, the user must input a game start date and start time so that reports will correspond to actual simulation game time (Janus post-processing files store time in seconds with 0 as the start time of the simulation). The user returns to the “ISRA Main Window” after clicking the “OK” button in the lower left-hand corner of the GUI. All buttons on the “ISRA Main Window” GUI are now active with the exception of the “Pause” button.

Defining NAIs

There is one more step that must be taken before running the S2A2, the definition of NAIs (Named Areas of Interest). NAIs are user defined locations on the battlefield. Although the S2A2 can be run before defining NAIs and NAIs can be defined at any time, it is recommended to define NAIs before running the S2A2 since the S2A2 will need NAIs to create indicators. To define NAIs click on the “Area/Names” button on the “ISRA Main Window” GUI. The “Setup Battlefield Geometry and Side/Task Force Names” GUI at Figure 9 will appear. This GUI allows the user to input circular NAIs or rectangular NAIs. Once one of the “Geometry Templates:” is highlighted a window will appear in the upper right hand corner of the GUI. This window allows for the input of the specific geometry data. Circular NAIs are defined by inputting a center point for the NAI

and a radius for the circle. Rectangular NAIs are really four-sided polygons and are defined by inputting the four corners of the polygon. Once NAIs are defined the S2A2 should be run.

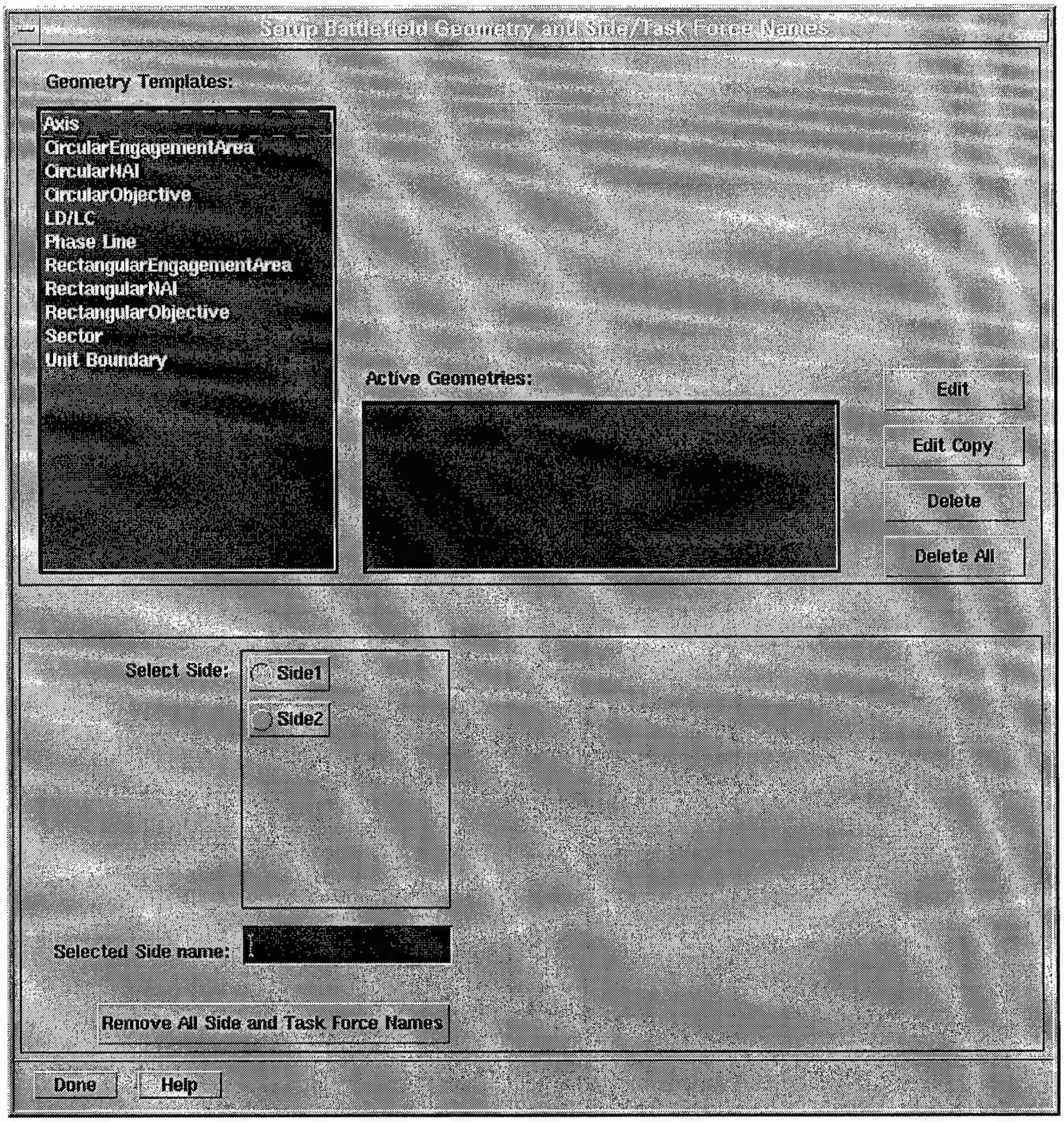

Figure 9. Setup Battlefield Geometry and Side/Task Force Names

Representing an S2's Logic

This leads to the second major issue in the development of the S2A2, how to represent the logic used by an S2 in making an assessment in the S2A2. Army Field

Manual 34-3, Collection Management and Synchronization Planning, and the author's personal experience as an S2 served as guides during the development of the S2A2.

Prior to getting into the detail of the S2A2 development, it is necessary to review the cognitive process used by an S2 when attempting to make an assessment on which COA the OPFOR is employing. The S2 has a good understanding of enemy weapons, equipment, organization and tactics. He uses this knowledge as background and then analyzes the terrain to determine how it can affect the enemy's deployment of equipment. The analysis of terrain as well as information that is previously know about the enemy, normally provided by higher headquarters, allows the S2 to develop an initial set of hypotheses that detail possible OPFOR COAs. Developing an initial set of hypotheses is a complex task. In most cases, the S2 breaks down the problem of determining an enemy COA into many smaller problems. This enables him to better manage the larger problem and create indicators or particular pieces of knowledge that may help him gather more in depth knowledge about a situation. Once the hypotheses are developed the S2 will attempt to prove or disprove each hypothesis. To do this he determines information gaps or information that pertains to a specific enemy COA and is unknown to the S2. The S2 uses these gaps when developing an intelligence collection plan and attempts to collect the unknown information. He will use the information provided by the collection plan to either confirm or deny the original hypotheses about the enemy COA.

Running the S2A2

The decomposing of a large problem (determining a COA that the enemy is employing) into smaller problems and the creation of indicators serve as the cornerstones of the S2A2 development. The development of the S2A2 will now be discussed by outlining the various S2A2 GUIs and the reasoning for certain S2A2 capabilities. To run the S2A2, the user must click the "S2A2" button, which will bring up the "S2A2 Main" GUI (Figure 10). This GUI provides the means to access other GUIs that will actually build a COA data set (a collection of indicators, rules, rule sets and COAs for a given scenario) as well as some setup commands for reporting, reading data and manipulating COA data set files. To load a current COA data set the user must enter the location of the COA and the name of the COA. The "Logfile:" field allows the user to define a name for a text file that will contain S2A2 reports. Every time a new logfile is to be created, the user must click the "Update Log" button. The "Reporting Addresses:" field is for entering the email address(es) for the recipient(s) of the S2A2 messages. More than one address is acceptable, as is a single address. The "Reporting Interval" and "Confidence Threshold" fields are used by the S2A2 for reporting purposes. The "Reporting Interval" field allows the user to specify how often (in minutes) the S2A2 should report. The "Confidence Threshold" is the minimum level of belief that a COA must attain in order for the S2A2 to report that the OPFOR is adopting that COA.

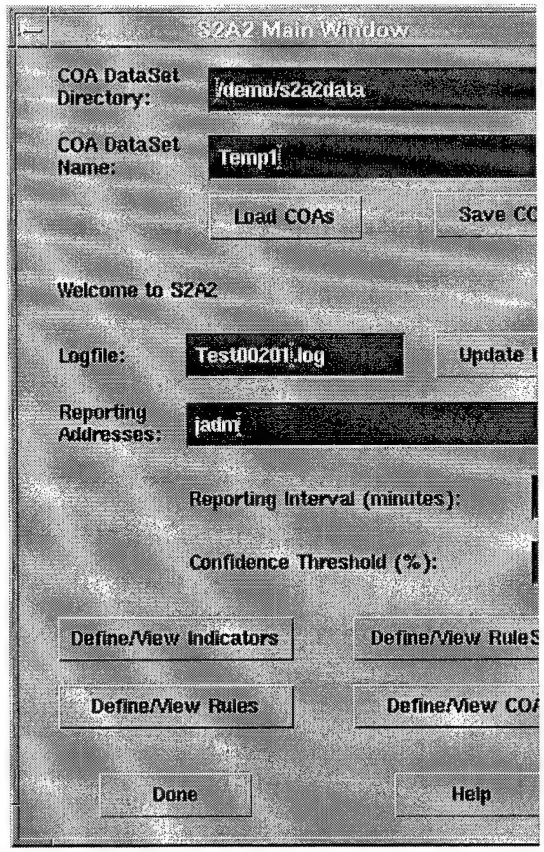

Figure 10. S2A2 Main Window

Creating Indicators

As previously stated, decomposing a COA into smaller, more manageable pieces of information, called indicators, is the fundamental basis of the S2A2. To create indicators, click the "Define/View Indicators" button. The GUI at Figure 11 will appear.

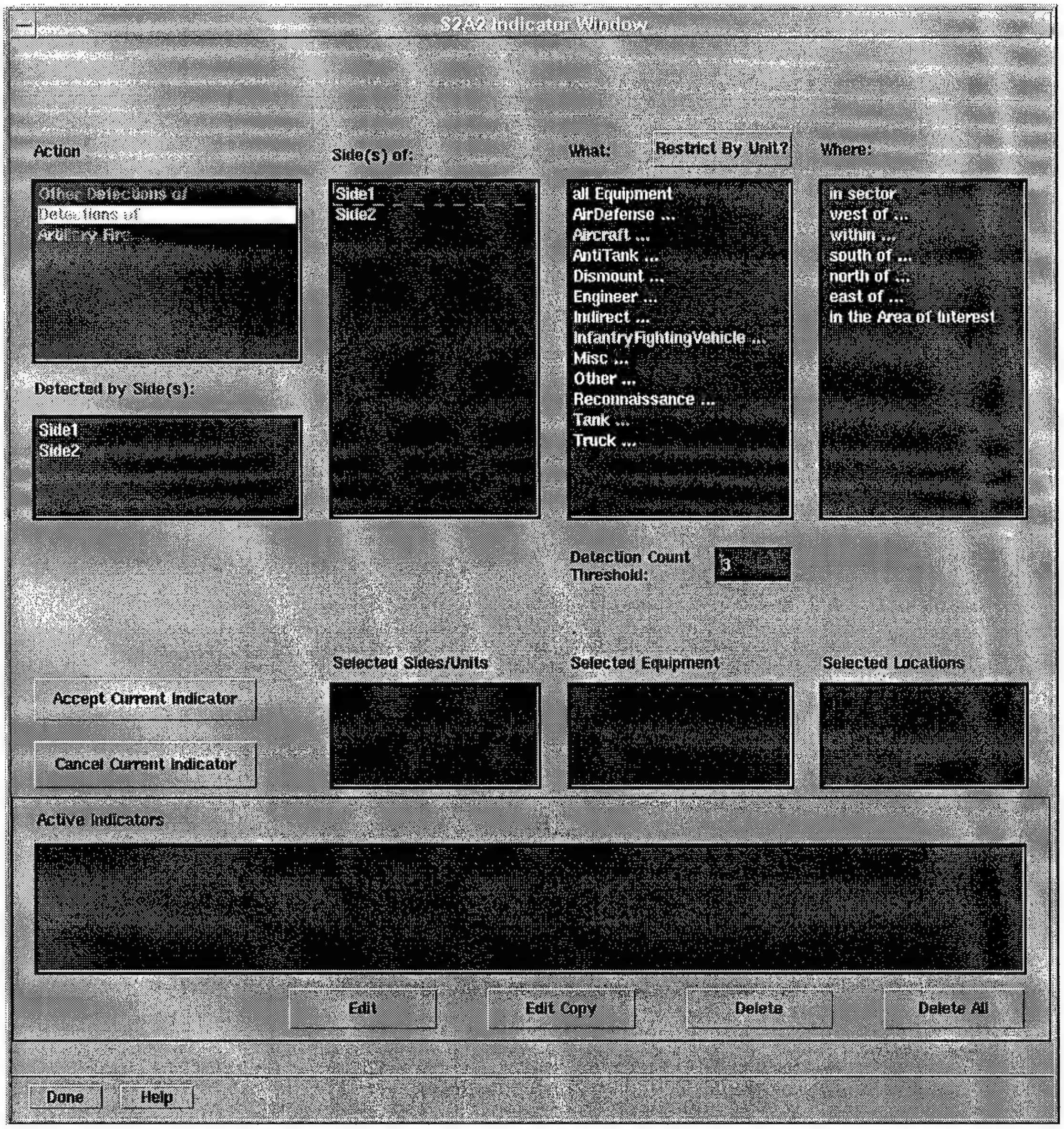

Figure 11. S2A2 Indicator Window

The "S2A2 Indicator Window" allows the user to build indicators to be used in defining rules. An indicator consists of a specific number of equipment at a given location or

artillery rounds impacting at a given location. The parameters of indicators are selected in the top portion of the screen.

The basic indicators are built from one of the three indicator templates shown under the selection box labeled "Action". Those are "Detections of", "Other Detections of" and "Artillery Fire". The "Detections of" indicator is simply the observation of a given Janus entity. It requires that the detected unit has been seen at least once by a unit from one of the sides selected in the "Detected by Side(s):" entry box for the detected unit to be counted. This indicator counts the total number of different elements of the "What:" equipment type observed within the "Where:" location over the most recent time period of interest. (The time period of interest is added to the indicator when it is used within a rule.) Note that five different tanks seen once each would be counted as five elements while one tank seen five times would only be counted as one element. This indicator is considered to be true when evaluated if the number of elements counted is at least as large as the number in the "Detection Count Threshold:" entry box.

The "Other Detections of" indicator is an artificial indicator that simulates surveillance assets, such as QUICKFIX or J-STARS, that are not replicated in the Janus simulation. It assumes a collection asset is positioned to observe the "Where:" location during the period between the "Start Time" and "Stop Time" and can detect all units that are moving. It uses all the inputs except for the "Detected by Side(s):" entry box. This indicator functions the same as the "Detections of" indicator except that the units do not have to be detected by another Janus unit but do have to be moving within the time period

bracketed by the entered "Start Time" and "Stop Time". (The absence of a "Start Time" entry assumes the beginning of the simulation is the "Start Time" and the absence of a "Stop Time" assumes there is no upper bound on the time period to consider.) The evaluation of this indicator is the same as for the "Detections of" indicator. Since this feature is a "work around" of the Janus simulation it is recommended to use this feature sparingly.

The "Artillery Fire" indicator is the reporting of impacted artillery rounds. It uses all the inputs except for the "Detected by Side(s):", "What:", "Start Time", and "Stop Time". It counts the number of artillery rounds impacting in the "Where:" location. This indicator is considered to be true when evaluated if the number of artillery rounds counted is at least as large as the number in the "Detection Count Threshold:" entry box.

The selection boxes labeled "Detected by Side(s):", "Side(s) of:", "What" and "Where" are used for filtering records by side, unit, type of equipment, and location, as applicable for the selected indicator template. The selection box labeled "Detected by Side(s):" refers to the side that is doing the observation. In all cases this will be the side that is represented as the friendly force in the Janus simulation. The selection box labeled "Side(s) of:" allows the user to select the side that is being observed. In all cases this will be the side that is represented as the OPFOR in the Janus simulation. Since it can be confusing remembering which side is the OPFOR and which side is the friendly force, the user can define a name for each side in the "Setup Battlefield Geometry and Side/Task Force Names" GUI (Figure 9). The box labeled "What:" is used to identify the

indicator's specific type of equipment. Clicking on a category will enable a sub menu that lists all the types of equipment in the category. As an example, clicking on "Tank" will enable a sub menu that lists all types of tanks. The "Restrict By Unit" button allows the user to further specify the exact unit from which the equipment is subordinate to. In other words the user can define an indicator that consists of all tanks from the 133rd Motorized Rifle Regiment. This feature should also be used sparingly because in reality a scout or observer would very rarely be able to identify the specific unit to which the equipment belongs. The "Where:" box is used to select the location on the battlefield where the user expects to observe the equipment. Clicking on a category will enable a sub menu that lists all battlefield geometry that were previously defined in the "Setup Battlefield and Side/Task Force Names" GUI (Figure 9).

Additionally, entry boxes for "Start Time (min):" and "Stop Time (min):" allow other entries that are also used for filtering records if "Other Detections of" was selected as the template. The "Detection Count Threshold:" entry box allows entry of a parameter used for evaluation of the truth of the rule using the indicator. It is the minimum number of pieces of equipment that must be detected and is essentially a logical greater than or equal to (>=) operand. At this time the S2A2 does not have the capability to process indicators that use the logical equal to (=) and less than (<) operands. This is because an S2 very rarely uses these operands when defining indicators.

Once an indicator is completed, selecting the "Accept Current Indicator" button adds it to the "Active Indicators" list and displays a compressed description of it in the

"Active Indicators" selection box in the lower portion of the screen. Selecting "Cancel Current Indicator" resets the top portion of the screen for entry of a new indicator.

The "Edit", "Edit Copy", "Delete", and "Delete All" apply to "Active Indicators". The "Edit" feature allows the user to edit a highlighted indicator. The "Edit Copy" feature creates a new indicator that is a duplicate of the highlighted indicator. The "Delete" and "Delete All" feature deletes a single highlighted indicator or all indicators. If an indicator is in use by a rule an error message will be displayed and the S2A2 will not delete the indicator. This feature protects the integrity of the COA data set.

Finally, the "Help" button brings up a help screen for the "S2A2 Indicator Window" and the "Done" button removes the "S2A2 Indicator Window" from view. These buttons are always available. The text file for this help screen is "IndicatorHelp.txt" located in the "helpfiles" subdirectory of the directory where the ISRA/SIFT/S2A2 executable is located.

Creating Rules

After indicators are created the next logical step is to build rules using the defined indicators. To create rules click the "Define/View Indicators" button in the S2A2 Main Window GUI. The GUI at Figure 12 will appear. The "S2A2 Rule Window" allows the user to build rules to be used in defining rule sets. Rules consist of indicators, a time window and a certainty factor. Rules may contain several indicators joined by an

operator (logical AND or logical OR). The time window is used to specify a given time period for when a rule must occur.

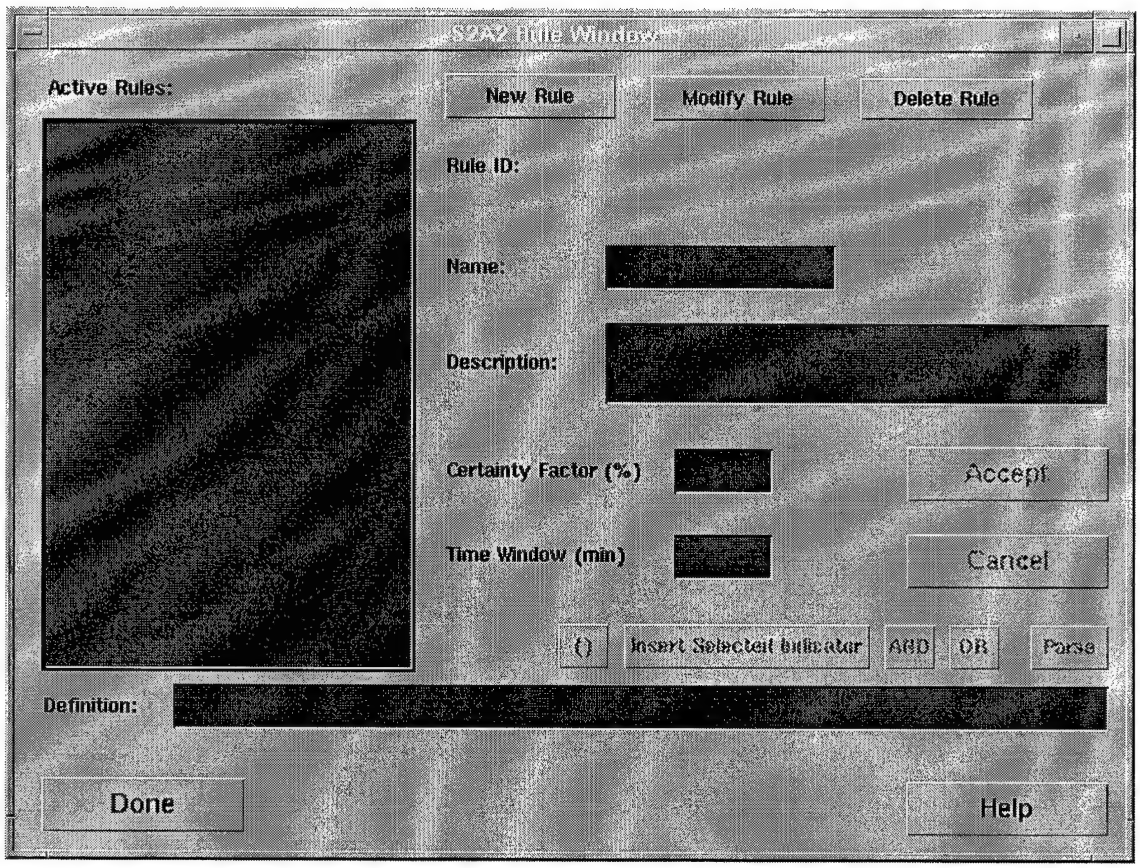

Figure 12. S2A2 Rule Window

A 30-minute time period means that all the indicators must be true within 30 minutes. A certainty factor is used to provide a level of belief for a rule.

The user must select one of the top three buttons, "New Rule", "Modify Rule", or Delete Rule" to create a new rule, modify an existing rule or delete an existing rule. What occurs when each is selected is described in separate paragraphs below. Selecting the "Cancel" button reactivates the three main buttons without taking action on any entries and returns all the entry boxes and buttons to their cleared and inactivated states. Selecting the "Accept" button takes action on the entries, if the entries are complete, or otherwise displays a red warning message describing the error. After action has been taken on completed entries, all the entry boxes and buttons return to their cleared and inactivated states.

Selecting the "New Rule" button changes the title of the selection/list box to "Available Indicators:", adds two radio buttons (labeled "All Indicators" and "Selected Only") below the selection/list box, displays an S2A2 generated unique rule identification number beside the "Rule ID:" label, and activates the remaining five entry boxes and five buttons associated with the "Definition:" entry box.

The name of the rule being created is made up of the "Rule ID:" with the entry from the "Name:" entry box added to it and separated from it by an underscore. For example, if the "Rule ID:" is "R1" and the "Name:" is "T-80 Detects", the name of the rule will become "R1_T-80 Detects" and this is the name that will be displayed in the "Active Rules:" list/selection box. The entry in the "Description:" box is a scratchpad for the S2 to tag useful information about the rule for viewing whenever the rule is selected.

The "Certainty Factor (%)" entry denotes how likely the S2 judges that the rule being true supports the rule set being true and, hence, the determination that the COA is being adopted. The data in the field must be input as an integer between –100 and 100. The "Time Window (min)" entry is the number of minutes that the rule being created will use for evaluating observations. For example, if a selected indicator shows a "Detection Count Threshold" of 5 and the "Time Window (min)" entry is 30, five observations will have to have been recorded within the last thirty minutes for that portion of the rule to be evaluated as true. Note that the "Time Window (min)" entry applies to every indicator selected for the rule.

The five buttons above the "Definition:" entry box are used to assist in the definition of the rule. The "()" button adds both left and right parentheses in the "Definition:" entry box. The "Insert Selected Indicator" button adds the highlighted indicator from the "Active Indicators:" list/selection box. The "AND" button adds the "&&" symbol for a logical AND operator and the "OR" button adds the "||" symbol for a logical OR operator. At this time the S2A2 does not have the capability to define rules using the logical NOT operand. The "Parse" button evaluates the defined rule's expression for correct syntax without accepting the rule. The user can alternatively type the entire rule expression in the "Definition:" box without using a single button, if desired, and selecting the "Accept" button activates the "Parse" function for syntax checking before the new rule is allowed to be created. Additionally, the user can use any combination of buttons and typing that suits the user.

To select the "Modify Rule" button requires that an existing rule shown in the "Active Rules:" selection/list box be clicked on and highlighted. Note that this action also displays all the information that was recorded when the rule was last accepted and thus allows the user to browse through the existing rules at any time. Then, when the "Modify Rule" button is selected, the rule is again active for the user to modify as if it had not been previously accepted. Selecting the "Accept" button replaces the previous version of the rule with the changed version and selecting the "Cancel" button leaves the previous version of the rule unchanged.

To select the "Delete Rule" button requires that an existing rule shown in the "Active Rules:" selection/list box be clicked on and highlighted. When the "Delete Rule" button is selected, the highlighted rule is removed and the "Active Rules:" selection/list box is refreshed with the deleted rule removed. If a rule is in use by a rule set an error message will be displayed and the S2A2 will not delete the rule. This feature protects the integrity of the COA data set. Also, "Rule ID:" numbers for deleted rules are reused by the S2A2 program when new rules are created after rules have been deleted.

Finally, the "Help" button brings up a help screen for the "S2A2 Rule Window" and the "Done" button removes the "S2A2 Rule Window" from view. These buttons are always available. The text file for this help screen is "s2a2rules.txt" located in the "helpfiles" subdirectory of the directory where the ISRA/SIFT/S2A2 executable is located.

Time Window Issue

One issue that arose during the development of the S2A2 was where to include the time window. There were two options for where to include the time window, as part of an indicator or as part of a rule. Ultimately the time window was included as a part of a rule. Since a rule can be a combination of indicators it made more sense to include the time window as a part of the rule. Including the time window in an indicator would lead to difficulty in the evaluation of rules with multiple indicators if the indicators had different time windows. Additionally, since an indicator may be used by multiple rules, providing the time window as a part of the rule gives the user more flexibility and reduces the number of indicators that must be created.

Creating Rule Sets

After rules are created the user can build rule sets from the available defined rules. To create rule sets click the "Define/View RuleSets" button in the S2A2 Main Window GUI. The GUI at Figure 13 will appear.

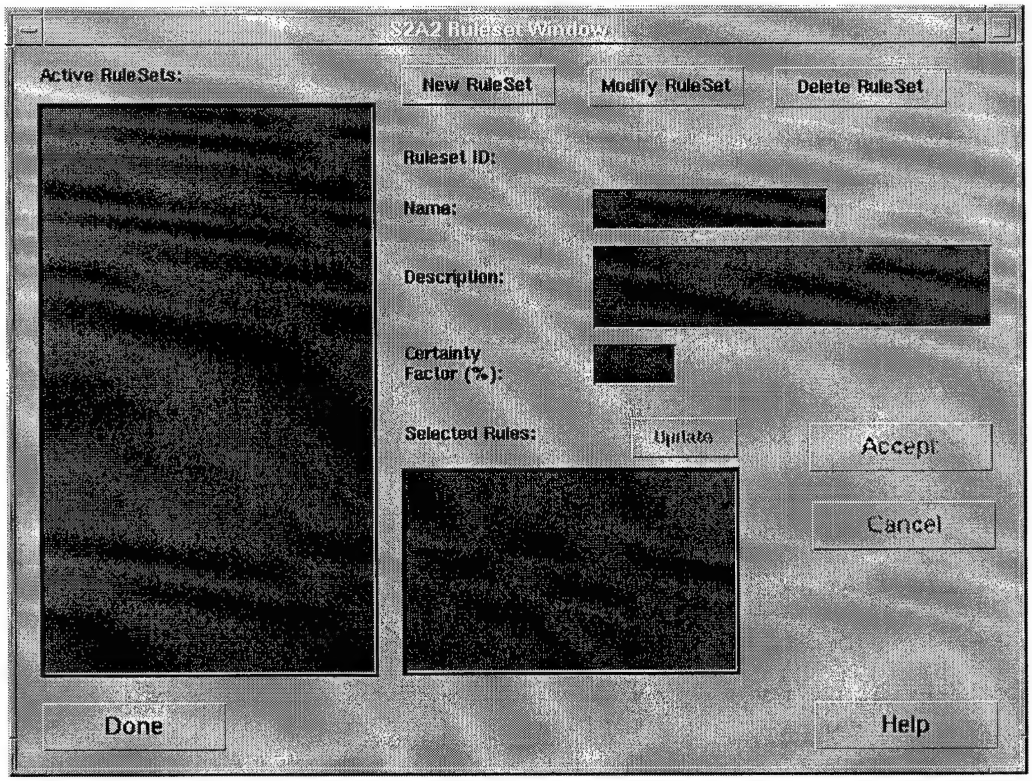

Figure 13. S2A2 Ruleset Window

The "S2A2 Ruleset Window" allows the user to build rule sets to be used in defining COAs. This menu works almost identically to the "S2A2 Rule Window" with some minor exceptions. The selection/list box on the left is titled as "Active Rulesets:" for the default and "Available Rules:" when the "New RuleSet" button has been selected. Substituting "RuleSet" for "Rule" and "Rules" for "Indicators" in the descriptions for the "S2A2 Rule Window" description results in a description that almost exactly matches the

actions for this menu. The major differences are that the rule sets have no independent time window and all the rules are logically related within a rule set by the "and" operator.

In creating a new rule set, the “Selected Rules:” list box replaces the “Definition:” entry box and the “Update” button replaces the five buttons associated with the previously described “Definition:” entry box. To select the rules, the desired rules are highlighted in the “Active Rules:” selection/list box in the order in which they are to be evaluated. When the “Update” button is selected, the highlighted Rules are entered in the “Selected Rules:” list box with the first Rule on the top of the list and the last rule on the bottom.

It is very important to note that sequencing of events or rules is done through the use of rule sets. The order of rules within a rule set denotes the order of events occurring on the battlefield. This means that in order for a rule set to be true, the rules that make up the rule set must be true in the order that they appear. In other words, if a rule set consists of three rules, Rule_1, Rule_2 and Rule_3, then in order for the rule set to be true, Rule_2 must be true after Rule_1 becomes true and Rule_3 must be true after Rule_2 becomes true.

If the order or specific rules selected need to be changed, the user can click on a highlighted rule in the “Active Rules:” selection/list box to un-highlight it. When only the correct rules are highlighted and have been selected in the correct order, the “Update” button is again selected and the currently highlighted rules replace the previous ones

shown in the “Selected Rules:” list box. The order of the new “Selected Rules:” is the order in which they were highlighted with the most recent on the bottom.

Finally, the “Help” button brings up a help screen for the “S2A2 Ruleset Window” and the “Done” button removes the “S2A2 Ruleset Window” from view. These buttons are always available. The text file for this help screen is “s2a2rulesets.txt” located in the “helpfiles” subdirectory of the directory where the ISRA/SIFT/S2A2 executable is located.

Creating COAs

After rules are created the next logical step is to build COAs using the defined rule sets. To create rules click the “Define/View COAs” button in the S2A2 Main Window GUI. The GUI at Figure 14 will appear.

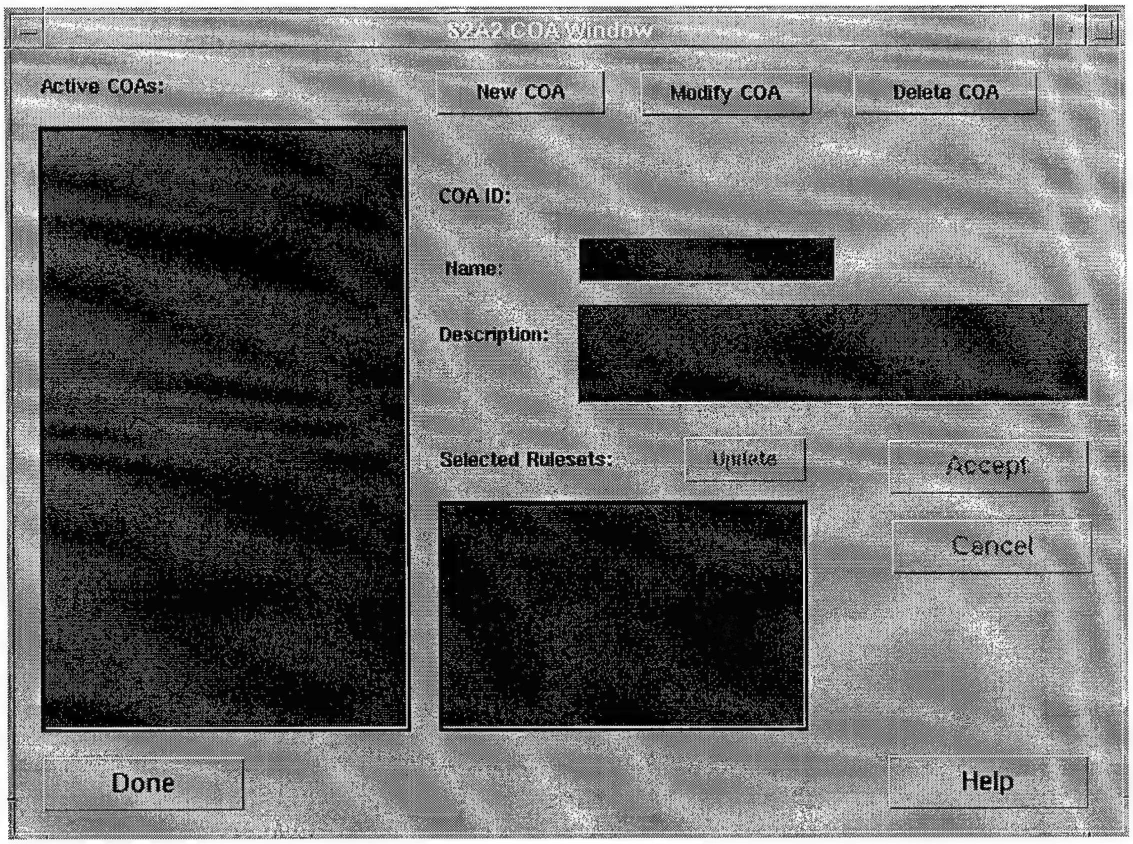

Figure 14. S2A2 COA Window

The "S2A2 COA Window" allows the user to build COAs to be used in determining which COA, if any, has been adopted by the OPFOR. This menu works almost identically to the "S2A2 Ruleset Window" with some minor exceptions. Substituting "COA" for "RuleSet" and "Ruleset" for "Rules" in the descriptions for the "S2A2 Rule Window" description results in a description that almost exactly matches the actions for

this menu. The only other difference is that the COAs have no certainty factor that is associated with the collection of rule sets that make up each of the COAs.

The calculated level of belief for each COAs evaluation is dependent on combining calculated level of belief for each of the rule sets that make up the COA. The COAs evaluated level of belief is then compared against the "Confidence Threshold" for COAs from the S2A2 Main Window (Figure 10) to determine if the COA should be designated as adopted by the OPFOR.

Finally, the "Help" button brings up a help screen for the "S2A2 COA Window" and the "Done" button removes the "S2A2 COA Window" from view. These buttons are always available. The text file for this help screen is "s2a2coas.txt" located in the "helpfiles" subdirectory of the directory where the ISRA/SIFT/S2A2 executable is located.

The S2A2 Data Process

The last developmental issue to be discussed is how the S2A2 processes data. The S2A2 data process can be considered as a loop. Data records are read from applicable post-processing files, active indicators are determined and appropriate data records are assigned to the active indicators, COAs are evaluated, and a report is sent to a logfile or e-mailed to a defined user. This process repeats itself until there are no more data records to be read.

Reading of Records

At every ISRA cycle (defined as a data read cycle) specific Janus post-processing files are read by ISRA based on which S2A2 indicators are active. The S2A2 primarily uses the movement, detection and artillery post-processing files. A specific number of records are read from each designated file and stored during each ISRA cycle for review by the S2A2. These records are not filtered during the read process.

Determination of Active Indicators

The S2A2 maintains a list of active indicators. Active indicators are indicators that are in use by non-true rules. Each of the indicators on the list of active indicators is called sequentially to execute the read and filter function. During this activity, each indicator checks the ISRA record storage locations that are specifically needed for that indicator. All records that are found are then filtered on the basis of Side, Unit, Type of Equipment, and Location. Every record that passes all the filters is copied by the indicator and stored locally within that indicator. At this point, a cleanup of records is performed within the indicator. Note that an indicator used by more than one rule could have a different Time Window for each rule. All "stale" records, i. e., all records that have a time tag older than the latest current time minus the largest "Time Window" for that indicator are removed so that only current records within the largest "Time Window" are kept.

Evaluation of COAs

As mentioned previously, the S2A2 uses the backward chaining control technique. Specifically the S2A2 uses a depth-first search when evaluation COAs. Durkin (1994) defines depth-first search as "a search techniques that looks for a solution along each branch of a problem space to its full vertical length, then proceeds in some defined order such as from left to right." An interim evaluation of a subset of active indicators using this technique is done every 60 seconds (of simulation time) to ensure that the S2A2 does not exclude any rule that may have become true. This indicators subset is determined by starting with each of the COAs and then sequentially tracing down the hierarchy through the highest priority non-true rule of each non-true rule set to every indicator used in the rules that are thus reached. The records in each indicator thus triggered are checked to determine the total number of unique elements that are recorded within the "Time Window" set by the rule that is using it. If that number is at least as large as the "Detection Count Threshold", that indicator is set as true for the rule being evaluated. If that particular rule has evaluated enough of its indicators that it has also been set to true, it evaluates each of its indicators for removal from the list of active indicators. If any of its indicators is not still needed by another rule, either currently or potentially in the future, those unneeded indicators are removed from the list of active indicators. (Once a rule is set as true within a rule set, it remains as true within that rule set from then on, but only within that rule set. If the rule is used in another rule set and has not been set as true in that other rule set, it is still non-true within that other rule set.)

Rules that have not been set to true after all of their indicators have been evaluated remain as non-true for evaluation at the next interim indicator/rule evaluation. At the completion of the interim indicator/rule evaluations, all indicators remaining on the list of active indicators are reset to non-true. Note that the remaining list of active indicators includes all indicators that are needed by every currently non-true rule.

After a rule set and all of its associated rules are evaluated, the S2A2 performs certainty factor arithmetic to determine a level of belief for the rule set. After the rule set level of belief is determined, it is added to the level of belief of its associated COA. This process is repeated for all rule sets and in every COA.

Reporting

After a period of simulation time has passed since the last COA report and during a cycle when an interim indicator/rule evaluation has been performed, a periodic COA report is generated. (That period of simulation time is equal to the number of minutes recorded in the S2A2 Main Window entry box labeled "Reporting Interval".) The calculated level of belief for each COA is compared against the number from the "S2A2 Main Window" entry box labeled "Confidence Threshold (%)". If the COA level of belief is at least as large as the "Confidence Threshold (%)" entered by the user, then S2A2 reports that the COA has been adopted by the OPFOR. Otherwise, the S2A2 reports that the COA has not been adopted by the OPFOR. The S2A2 makes its determination for every COA and reports the COA level of belief as well as how many

rules of each rule set have evaluated to true. The reports are sent via email to every address listed in the "Reporting Addresses:" entry box on the "S2A2 Main Menu" and are recorded in the file listed in the "Logfile:" entry box, also on the "S2A2 Main Menu."

APPENDIX B

VERIFICATION SCENARIOS

The purpose of the verification test was to ensure that the logic and code of the S2A2 functions properly. The verification of the S2A2 included testing sets of code separately before conducting a composite test. The specific objectives of the verification were as follows:

1. Test to ensure that rules are processed properly.
    a. Indicators are being counted properly.
    b. The logic (AND, OR) of a rule works properly.
    c. The rule time window works properly
2. Test to ensure that rule sets are processed properly.
    a. Only the highest level non-true rule is processed.
    b. Rule set certainty factor arithmetic functions properly.
3. Test to ensure that COAs are processed properly.
    a. All rule sets are processed at each evaluation.
    b. COA certainty factor arithmetic functions properly.
4. Test to ensure the reporting works properly.
    a. Reports are generated according to the user specified interval.
    b. COAs are identified as being adopted by the OPFOR if they meet or exceed the user specified threshold.
    c. COAs are identified as not being adopted by the OPFOR if they don't exceed the user specified threshold.
    d. All COAs are reported on.

To meet these objectives a simple scenario was used. This scenario was used for both the individual test of code as well as the composite test. It consisted of six friendly force scout teams located on a hilltop observing the east/west movement of an armor battalion (30 T-72 tanks). The tanks moved along two avenues of approach (AA) with the scout teams in defilade observing six NAIs along those AAs. A graphical representation of the scenario is at Figure 4.

NAIs 1 – 3 were located along the avenue of approach in the north and NAIs 4 – 6 were located along the avenue of approach in the south. Different movement routes of the tanks comprised three distinct COAs. The first COA, COA North, had all 30 tanks moving along AA North. The second COA, COA Split, had 15 tanks moving along AA North and 15 tanks moving along AA South. The third COA, COA South had all 30 tanks moving along AA South. Each scenario or COA was run in Janus with the scenario lasting about 32 minutes (the time it took the tanks to move through the appropriate NAIs, 32 minutes for COA North, 32 minutes for COA Split and 36 minutes for COA South). During all scenarios there were no direct or indirect fire engagements.

Battlefield geometry was created for the six NAIs. The following table lists the six circular NAIs in the verification scenario.

Table 7

Verification Scenario NAIs

NAI	LOCATION	RADIUS
1	24001950	400 meters
2	25031900	400 meters
3	26201870	500 meters
4	22201800	400 meters
5	23401700	400 meters
6	24301590	400 meters

Indicators, rules and rule sets were constructed to determine which COA the enemy was employing. The following table outlines the indicators for the verification scenario.

Table 8

Verification Scenario Indicators

INDICATOR	COUNT	EQUIPMENT	LOCATION	AA
1	20	T-72	NAI 1	North
2	20	T-72	NAI 2	North
3	20	T-72	NAI 3	North
4	20	T-72	NAI 4	North
5	20	T-72	NAI 5	North
6	20	T-72	NAI 6	North
7	10	T-72	NAI 1	South
8	10	T-72	NAI 2	South
9	10	T-72	NAI 3	South
10	10	T-72	NAI 4	South
11	10	T-72	NAI 5	South
12	10	T-72	NAI 6	South

Indicators 1 – 3 and 7 - 9 were used to identify tanks moving along AA North, and indicators 4 – 6 and 10 - 12 were used to identify tanks moving along AA South. The threshold of 20 T-72 tanks for indicators 1- 6 allowed for the detection of the OPFOR using COA North or COA South while the threshold of 10 T-72 tanks for indicators 7 – 12 allowed for the detection of the OPFOR using COA Split. As a note, 20 T-72s to the North and 10 to the South would trigger both COA North and COA Split. A similar dual trigger occurs for 20 T-72s to the South and 10 to the North.

The table below outlines the rules for the verification scenario.

Table 9

Verification Scenario Rules

RULE	INDICATOR (AA-COUNT)	TIME WINDOW	CERTAINTY FACTOR	COA SUPPORTED
1	I1 (N-20)	10 Minutes	90%	1 (North)
2	I2 (N-20)	10 Minutes	90%	1 (North)
3	I3 (N-20)	10 Minutes	90%	1 (North)
4	I7 (N-10)	10 Minutes	90%	2 (Split)
5	I8 (N-10)	10 Minutes	90%	2 (Split)
6	I9 (N-10)	10 Minutes	90%	2 (Split)
7	I10 (S-10)	10 Minutes	90%	2 (Split)
8	I11 (S-10)	10 Minutes	90%	2 (Split)
9	I12 (S-10)	10 Minutes	90%	2 (Split)
10	I4 (S-20)	10 Minutes	90%	3 (South)
11	I5 (S-20)	10 Minutes	90%	3 (South)
12	16 (S-20)	10 Minutes	90%	3 (South)
13	I1 $\wedge$ I2 (N-20)	30 Minutes	90%	1 (North)
14	I10 $\wedge$ I11 $\wedge$ I12 (S-10)	30 Minutes	90%	2 (Split)
15	I5 $\wedge$ I6 (S-20)	30 Minutes	90%	3 (South)

The majority of the rules are simple, one-indicator rules. Rule numbers 13 – 15 were used to test the logic of a rule. Table 10 is the list of rule sets used.

Table 10

Verification Scenario Rule Sets

RULE SETS	RULES	CERTAINTY FACTOR	COA SUPPORTED
1	R1	30%	1 (North)
2	R2	30%	1 (North)
3	R3	30%	1 (North)
4	R1, R2	50%	1 (North)
5	R1, R3	50%	1 (North)
6	R2, R3	50%	1 (North)
7	R1, R2, R3	90%	1 (North)
8	R4, R5	15%	2 (Split)
9	R4, R6	15%	2 (Split)
10	R5, R6	15%	2 (Split)
11	R7, R8	15%	2 (Split)
12	R7, R9	15%	2 (Split)
13	R8, R9	15%	2 (Split)
14	R4, R5, R6	50%	2 (Split)
15	R7, R8, R9	50%	2 (Split)
16	R10	30%	3 (South)
17	R11	30%	3 (South)
18	R12	30%	3 (South)
19	R10, R11	50%	3 (South)
20	R10, R12	50%	3 (South)
21	R11, R12	50%	3 (South)
22	R11, R12	90%	3 (South)
23	R7, R8, R9	- 90%	3 (South)
24	R4, R5, R6	- 90%	1 (North)
25	R13	- 50%	2 (Split)
26	R10, R11	- 50%	2 (Split)
27	R10, R11, R12	- 90%	2 (Split)
28	R10, R11, R12	- 90%	2 (Split)

As you can see rule sets contained both single and multiple rules. This was added to compensate for one or more indicators not being able to report. Multiple rules were also used to test if the rule sets were being evaluated properly. Rule sets with a negative certainty factor were added to reduce a COAs level of belief when there was evidence of another COA being adopted as well as to test negative certainty factor arithmetic. Those were rule sets 23 – 28. Rule set 23 had a certainty factor of –90% and was used to decrease the level of belief for COA North if any of the other two COAs were being adopted. Similarly, rule set 24 was used to decrease the level of belief for COA South if any of the other two COAs were adopted. Since the rules associated with the movement of 10 tanks or more through any of the six NAIs would trigger rules for COA Split, rule sets (rule sets 25 – 28) to decrement the level of belief were added to COA Split to discriminate between the three COAs. In other words, if COA North was being adopted and 30 tanks moved through NAIs 1 – 3, rules would become true for COA Split since the threshold level for indicators within COA Split's rules were set to 10. This brings up a very important point when creating rules and rule sets for a given set of COAs. The user must be careful to distinguish between COAs and ensure that a mechanism is in place if an event can trigger rules that are used by more than one COA.

The following table outlines the COAs for the verification scenario.

Table 11

Verification Scenario COAs

COA	RULE SETS
1 (North)	RS1, RS2, RS3, RS4, RS5, RS6, RS7, RS23
2 (Split)	RS8, RS9, RS10, RS11, RS12, RS13, RS14, RS15, RS25, RS26, RS27, RS28
3 (South)	RS16, RS17, RS18, RS19, RS20, RS21, RS22, RS24

APPENDIX C

S2A2 VERIFICATION TEST OUTPUT

The verification test used three scenarios that coincided with three distinctly different OPFOR COAs. In scenario 1 the OPFOR's maneuvered all 30 of its T-72 tanks using AA North. The S2A2 COA that detects this scenario is COA North. In scenario 2 the OPFOR maneuvered 15 of its T-72 tanks using AA North and 15 of its T-72 tanks using AA South. The S2A2 COA for this scenario is COA Split. The OPFOR maneuvered all 30 of its T-72 tanks using AA South in the third scenario third COA, COA South had all 30 tanks moving along AA South. COA South is the name of the S2A2 COA for this scenario. The outputs for each scenario are as follows.

Scenario 1

COA Status Report for time 241104Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 0%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset1	0%	0%	0/ 1	0/ 1
	ruleset2	0%	0%	0/ 1	0/ 1
	ruleset3	0%	0%	0/ 1	0/ 1
	ruleset4	0%	0%	0/ 1	0/ 1
	ruleset5	0%	0%	0/ 2	0/ 2
	ruleset6	0%	0%	0/ 2	0/ 2
	ruleset7	0%	0%	0/ 3	0/ 3
	ruleset23	0%	0%	0/ 3	0/ 3

-- COA Split Confidence Factor 0%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset8	0%	0%	0/ 2	0/ 2
	ruleset9	0%	0%	0/ 2	0/ 2
	ruleset10	0%	0%	0/ 2	0/ 2
	ruleset11	0%	0%	0/ 2	0/ 2
	ruleset12	0%	0%	0/ 2	0/ 2
	ruleset13	0%	0%	0/ 2	0/ 2
	ruleset14	0%	0%	0/ 3	0/ 3

ruleset15	0%	0%	0/ 1	0/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 0%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	0%	0%	0/ 1	0/ 1
ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2
ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	0%	0%	0/ 3	0/ 3

COA Status Report for time 241108Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 27%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	27%	0%	1/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	1/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	1/ 3	0/ 3
ruleset23	0%	0%	0/ 3	0/ 3

-- COA Split Confidence Factor 0%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	0%	0%	1/ 2	0/ 2
ruleset9	0%	0%	1/ 2	0/ 2
ruleset10	0%	0%	0/ 2	0/ 2
ruleset11	0%	0%	0/ 2	0/ 2
ruleset12	0%	0%	0/ 2	0/ 2
ruleset13	0%	0%	0/ 2	0/ 2
ruleset14	0%	0%	1/ 3	0/ 3
ruleset15	0%	0%	0/ 1	0/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3
ruleset28	0%	0%	1/ 3	0/ 3

-- COA South Confidence Factor 0%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset16	0%	0%	0/ 1	0/ 1
	ruleset17	0%	0%	0/ 1	0/ 1
	ruleset18	0%	0%	0/ 1	0/ 1
	ruleset19	0%	0%	0/ 2	0/ 2
	ruleset20	0%	0%	0/ 2	0/ 2
	ruleset21	0%	0%	0/ 1	0/ 1
	ruleset22	0%	0%	0/ 3	0/ 3
	ruleset24	0%	0%	1/ 3	0/ 3

COA Status Report for time 241112Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 27%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset1	27%	27%	1/ 1	1/ 1
	ruleset2	0%	0%	0/ 1	0/ 1
	ruleset3	0%	0%	0/ 1	0/ 1
	ruleset4	0%	0%	0/ 1	0/ 1
	ruleset5	0%	0%	1/ 2	1/ 2
	ruleset6	0%	0%	0/ 2	0/ 2
	ruleset7	0%	0%	1/ 3	1/ 3
	ruleset23	0%	0%	0/ 3	0/ 3

-- COA Split Confidence Factor 13%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset8	13%	0%	2/ 2	1/ 2
	ruleset9	0%	0%	1/ 2	1/ 2
	ruleset10	0%	0%	1/ 2	0/ 2
	ruleset11	0%	0%	0/ 2	0/ 2
	ruleset12	0%	0%	0/ 2	0/ 2
	ruleset13	0%	0%	0/ 2	0/ 2
	ruleset14	0%	0%	2/ 3	1/ 3
	ruleset15	0%	0%	0/ 1	0/ 1
	ruleset25	0%	0%	0/ 1	0/ 1
	ruleset26	0%	0%	0/ 2	0/ 2
	ruleset27	0%	0%	0/ 3	0/ 3
	ruleset28	0%	0%	1/ 3	1/ 3

-- COA South Confidence Factor 0%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset16	0%	0%	0/ 1	0/ 1

ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2
ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	0%	0%	2/ 3	1/ 3

COA Status Report for time 241116Z

It appears that the OPFOR is adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 98%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	27%	27%	1/ 1	1/ 1
ruleset2	27%	0%	1/ 1	0/ 1
ruleset3	27%	0%	1/ 1	0/ 1
ruleset4	45%	0%	1/ 1	0/ 1
ruleset5	45%	0%	2/ 2	1/ 2
ruleset6	45%	0%	2/ 2	0/ 2
ruleset7	81%	0%	3/ 3	1/ 3
ruleset23	0%	0%	0/ 3	0/ 3

-- COA Split Confidence Factor -70%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	13%	13%	2/ 2	2/ 2
ruleset9	13%	0%	2/ 2	1/ 2
ruleset10	13%	0%	2/ 2	1/ 2
ruleset11	0%	0%	0/ 2	0/ 2
ruleset12	0%	0%	0/ 2	0/ 2
ruleset13	0%	0%	0/ 2	0/ 2
ruleset14	45%	0%	3/ 3	2/ 3
ruleset15	0%	0%	0/ 1	0/ 1
ruleset25	-45%	0%	1/ 1	0/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3
ruleset28	-81%	0%	3/ 3	1/ 3

-- COA South Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	0%	0%	0/ 1	0/ 1
ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2
ruleset21	0%	0%	0/ 1	0/ 1

ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	-81%	0%	3/ 3	2/ 3

COA Status Report for time 241120Z

It appears that the OPFOR is adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 98%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	27%	27%	1/ 1	1/ 1
ruleset2	27%	27%	1/ 1	1/ 1
ruleset3	27%	27%	1/ 1	1/ 1
ruleset4	45%	45%	1/ 1	1/ 1
ruleset5	45%	45%	2/ 2	2/ 2
ruleset6	45%	45%	2/ 2	2/ 2
ruleset7	81%	81%	3/ 3	3/ 3
ruleset23	0%	0%	0/ 3	0/ 3

-- COA Split Confidence Factor -70%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	13%	13%	2/ 2	2/ 2
ruleset9	13%	13%	2/ 2	2/ 2
ruleset10	13%	13%	2/ 2	2/ 2
ruleset11	0%	0%	0/ 2	0/ 2
ruleset12	0%	0%	0/ 2	0/ 2
ruleset13	0%	0%	0/ 2	0/ 2
ruleset14	45%	45%	3/ 3	3/ 3
ruleset15	0%	0%	0/ 1	0/ 1
ruleset25	-45%	-45%	1/ 1	1/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3
ruleset28	-81%	-81%	3/ 3	3/ 3

-- COA South Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	0%	0%	0/ 1	0/ 1
ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2
ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	-81%	-81%	3/ 3	3/ 3

COA Status Report for time 241124Z

It appears that the OPFOR is adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 98%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset1	27%	27%	1/ 1	1/ 1
	ruleset2	27%	27%	1/ 1	1/ 1
	ruleset3	27%	27%	1/ 1	1/ 1
	ruleset4	45%	45%	1/ 1	1/ 1
	ruleset5	45%	45%	2/ 2	2/ 2
	ruleset6	45%	45%	2/ 2	2/ 2
	ruleset7	81%	81%	3/ 3	3/ 3
	ruleset23	0%	0%	0/ 3	0/ 3

-- COA Split Confidence Factor -70%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset8	13%	13%	2/ 2	2/ 2
	ruleset9	13%	13%	2/ 2	2/ 2
	ruleset10	13%	13%	2/ 2	2/ 2
	ruleset11	0%	0%	0/ 2	0/ 2
	ruleset12	0%	0%	0/ 2	0/ 2
	ruleset13	0%	0%	0/ 2	0/ 2
	ruleset14	45%	45%	3/ 3	3/ 3
	ruleset15	0%	0%	0/ 1	0/ 1
	ruleset25	-45%	-45%	1/ 1	1/ 1
	ruleset26	0%	0%	0/ 2	0/ 2
	ruleset27	0%	0%	0/ 3	0/ 3
	ruleset28	-81%	-81%	3/ 3	3/ 3

-- COA South Confidence Factor -81%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset16	0%	0%	0/ 1	0/ 1
	ruleset17	0%	0%	0/ 1	0/ 1
	ruleset18	0%	0%	0/ 1	0/ 1
	ruleset19	0%	0%	0/ 2	0/ 2
	ruleset20	0%	0%	0/ 2	0/ 2
	ruleset21	0%	0%	0/ 1	0/ 1
	ruleset22	0%	0%	0/ 3	0/ 3
	ruleset24	-81%	-81%	3/ 3	3/ 3

COA Status Report for time 241128Z

It appears that the OPFOR is adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 98%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset1	27%	27%	1/ 1	1/ 1
	ruleset2	27%	27%	1/ 1	1/ 1
	ruleset3	27%	27%	1/ 1	1/ 1
	ruleset4	45%	45%	1/ 1	1/ 1
	ruleset5	45%	45%	2/ 2	2/ 2
	ruleset6	45%	45%	2/ 2	2/ 2
	ruleset7	81%	81%	3/ 3	3/ 3
	ruleset23	0%	0%	0/ 3	0/ 3

-- COA Split Confidence Factor -70%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset8	13%	13%	2/ 2	2/ 2
	ruleset9	13%	13%	2/ 2	2/ 2
	ruleset10	13%	13%	2/ 2	2/ 2
	ruleset11	0%	0%	0/ 2	0/ 2
	ruleset12	0%	0%	0/ 2	0/ 2
	ruleset13	0%	0%	0/ 2	0/ 2
	ruleset14	45%	45%	3/ 3	3/ 3
	ruleset15	0%	0%	0/ 1	0/ 1
	ruleset25	-45%	-45%	1/ 1	1/ 1
	ruleset26	0%	0%	0/ 2	0/ 2
	ruleset27	0%	0%	0/ 3	0/ 3
	ruleset28	-81%	-81%	3/ 3	3/ 3

-- COA South Confidence Factor -81%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset16	0%	0%	0/ 1	0/ 1
	ruleset17	0%	0%	0/ 1	0/ 1
	ruleset18	0%	0%	0/ 1	0/ 1
	ruleset19	0%	0%	0/ 2	0/ 2
	ruleset20	0%	0%	0/ 2	0/ 2
	ruleset21	0%	0%	0/ 1	0/ 1
	ruleset22	0%	0%	0/ 3	0/ 3
	ruleset24	-81%	-81%	3/ 3	3/ 3

COA Status Report for time 241132Z

It appears that the OPFOR is adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 98%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset1	27%	27%	1/ 1	1/ 1
	ruleset2	27%	27%	1/ 1	1/ 1
	ruleset3	27%	27%	1/ 1	1/ 1

ruleset4	45%	45%	1/ 1	1/ 1
ruleset5	45%	45%	2/ 2	2/ 2
ruleset6	45%	45%	2/ 2	2/ 2
ruleset7	81%	81%	3/ 3	3/ 3
ruleset23	0%	0%	0/ 3	0/ 3

-- COA Split Confidence Factor -70%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	13%	13%	2/ 2	2/ 2
ruleset9	13%	13%	2/ 2	2/ 2
ruleset10	13%	13%	2/ 2	2/ 2
ruleset11	0%	0%	0/ 2	0/ 2
ruleset12	0%	0%	0/ 2	0/ 2
ruleset13	0%	0%	0/ 2	0/ 2
ruleset14	45%	45%	3/ 3	3/ 3
ruleset15	0%	0%	0/ 1	0/ 1
ruleset25	-45%	-45%	1/ 1	1/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3
ruleset28	-81%	-81%	3/ 3	3/ 3

-- COA South Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	0%	0%	0/ 1	0/ 1
ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2
ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	-81%	-81%	3/ 3	3/ 3

Scenario 2

COA Status Report for time 241104Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 0%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1

ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	0%	0%	0/ 3	0/ 3

-- COA Split Confidence Factor 0%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	0%	0%	0/ 2	0/ 2
ruleset9	0%	0%	0/ 2	0/ 2
ruleset10	0%	0%	0/ 2	0/ 2
ruleset11	0%	0%	0/ 2	0/ 2
ruleset12	0%	0%	0/ 2	0/ 2
ruleset13	0%	0%	0/ 2	0/ 2
ruleset14	0%	0%	0/ 3	0/ 3
ruleset15	0%	0%	0/ 1	0/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 0%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	0%	0%	0/ 1	0/ 1
ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2
ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	0%	0%	0/ 3	0/ 3

COA Status Report for time 241108Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 0%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	0%	0%	1/ 3	0/ 3

-- COA Split Confidence Factor 0%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset8	0%	0%	1/ 2	0/ 2
	ruleset9	0%	0%	1/ 2	0/ 2
	ruleset10	0%	0%	0/ 2	0/ 2
	ruleset11	0%	0%	1/ 2	0/ 2
	ruleset12	0%	0%	1/ 2	0/ 2
	ruleset13	0%	0%	0/ 2	0/ 2
	ruleset14	0%	0%	1/ 3	0/ 3
	ruleset15	0%	0%	0/ 1	0/ 1
	ruleset25	0%	0%	0/ 1	0/ 1
	ruleset26	0%	0%	0/ 2	0/ 2
	ruleset27	0%	0%	0/ 3	0/ 3
	ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 0%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset16	0%	0%	0/ 1	0/ 1
	ruleset17	0%	0%	0/ 1	0/ 1
	ruleset18	0%	0%	0/ 1	0/ 1
	ruleset19	0%	0%	0/ 2	0/ 2
	ruleset20	0%	0%	0/ 2	0/ 2
	ruleset21	0%	0%	0/ 1	0/ 1
	ruleset22	0%	0%	0/ 3	0/ 3
	ruleset24	0%	0%	1/ 3	0/ 3

COA Status Report for time 241112Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 0%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset1	0%	0%	0/ 1	0/ 1
	ruleset2	0%	0%	0/ 1	0/ 1
	ruleset3	0%	0%	0/ 1	0/ 1
	ruleset4	0%	0%	0/ 1	0/ 1
	ruleset5	0%	0%	0/ 2	0/ 2
	ruleset6	0%	0%	0/ 2	0/ 2
	ruleset7	0%	0%	0/ 3	0/ 3
	ruleset23	0%	0%	2/ 3	1/ 3

-- COA Split Confidence Factor 13%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset8	0%	0%	1/ 2	1/ 2

ruleset9	0%	0%	1/ 2	1/ 2
ruleset10	0%	0%	0/ 2	0/ 2
ruleset11	13%	0%	2/ 2	1/ 2
ruleset12	0%	0%	1/ 2	1/ 2
ruleset13	0%	0%	1/ 2	0/ 2
ruleset14	0%	0%	1/ 3	1/ 3
ruleset15	0%	0%	0/ 1	0/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 0%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	0%	0%	0/ 1	0/ 1
ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2
ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	0%	0%	1/ 3	1/ 3

COA Status Report for time 241116Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 0%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	0%	0%	2/ 3	2/ 3

-- COA Split Confidence Factor 69%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	13%	0%	2/ 2	1/ 2
ruleset9	13%	0%	2/ 2	1/ 2
ruleset10	13%	0%	2/ 2	0/ 2
ruleset11	13%	13%	2/ 2	2/ 2
ruleset12	0%	0%	1/ 2	1/ 2
ruleset13	0%	0%	1/ 2	1/ 2

ruleset14	45%	0%	3/ 3	1/ 3
ruleset15	0%	0%	0/ 1	0/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	0%	0%	0/ 1	0/ 1
ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2
ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	-81%	0%	3/ 3	1/ 3

COA Status Report for time 241120Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	-81%	0%	3/ 3	2/ 3

-- COA Split Confidence Factor 87%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	13%	13%	2/ 2	2/ 2
ruleset9	13%	13%	2/ 2	2/ 2
ruleset10	13%	13%	2/ 2	2/ 2
ruleset11	13%	13%	2/ 2	2/ 2
ruleset12	13%	0%	2/ 2	1/ 2
ruleset13	13%	0%	2/ 2	1/ 2
ruleset14	45%	45%	3/ 3	3/ 3
ruleset15	45%	0%	1/ 1	0/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3

ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	0%	0%	0/ 1	0/ 1
ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2
ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	-81%	-81%	3/ 3	3/ 3

COA Status Report for time 241124Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	-81%	-81%	3/ 3	3/ 3

-- COA Split Confidence Factor 87%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	13%	13%	2/ 2	2/ 2
ruleset9	13%	13%	2/ 2	2/ 2
ruleset10	13%	13%	2/ 2	2/ 2
ruleset11	13%	13%	2/ 2	2/ 2
ruleset12	13%	13%	2/ 2	2/ 2
ruleset13	13%	13%	2/ 2	2/ 2
ruleset14	45%	45%	3/ 3	3/ 3
ruleset15	45%	45%	1/ 1	1/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules

ruleset16	0%	0%	0/ 1	0/ 1
ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2
ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	-81%	-81%	3/ 3	3/ 3

COA Status Report for time 241128Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	-81%	-81%	3/ 3	3/ 3

-- COA Split Confidence Factor 87%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	13%	13%	2/ 2	2/ 2
ruleset9	13%	13%	2/ 2	2/ 2
ruleset10	13%	13%	2/ 2	2/ 2
ruleset11	13%	13%	2/ 2	2/ 2
ruleset12	13%	13%	2/ 2	2/ 2
ruleset13	13%	13%	2/ 2	2/ 2
ruleset14	45%	45%	3/ 3	3/ 3
ruleset15	45%	45%	1/ 1	1/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	0%	0%	0/ 1	0/ 1
ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2

ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	-81%	-81%	3/ 3	3/ 3

COA Status Report for time 241132Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	-81%	-81%	3/ 3	3/ 3

-- COA Split Confidence Factor 87%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	13%	13%	2/ 2	2/ 2
ruleset9	13%	13%	2/ 2	2/ 2
ruleset10	13%	13%	2/ 2	2/ 2
ruleset11	13%	13%	2/ 2	2/ 2
ruleset12	13%	13%	2/ 2	2/ 2
ruleset13	13%	13%	2/ 2	2/ 2
ruleset14	45%	45%	3/ 3	3/ 3
ruleset15	45%	45%	1/ 1	1/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	0%	0%	0/ 2	0/ 2
ruleset27	0%	0%	0/ 3	0/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	0%	0%	0/ 1	0/ 1
ruleset17	0%	0%	0/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	0%	0%	0/ 2	0/ 2
ruleset20	0%	0%	0/ 2	0/ 2
ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	0/ 3	0/ 3
ruleset24	-81%	-81%	3/ 3	3/ 3

Scenario 3

COA Status Report for time 241104Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 0%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset1	0%	0%	0/ 1	0/ 1
	ruleset2	0%	0%	0/ 1	0/ 1
	ruleset3	0%	0%	0/ 1	0/ 1
	ruleset4	0%	0%	0/ 1	0/ 1
	ruleset5	0%	0%	0/ 2	0/ 2
	ruleset6	0%	0%	0/ 2	0/ 2
	ruleset7	0%	0%	0/ 3	0/ 3
	ruleset23	0%	0%	1/ 3	0/ 3

-- COA Split Confidence Factor 0%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset8	0%	0%	0/ 2	0/ 2
	ruleset9	0%	0%	0/ 2	0/ 2
	ruleset10	0%	0%	0/ 2	0/ 2
	ruleset11	0%	0%	1/ 2	0/ 2
	ruleset12	0%	0%	1/ 2	0/ 2
	ruleset13	0%	0%	0/ 2	0/ 2
	ruleset14	0%	0%	0/ 3	0/ 3
	ruleset15	0%	0%	0/ 1	0/ 1
	ruleset25	0%	0%	0/ 1	0/ 1
	ruleset26	0%	0%	1/ 2	0/ 2
	ruleset27	0%	0%	1/ 3	0/ 3
	ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 27%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset16	27%	0%	1/ 1	0/ 1
	ruleset17	0%	0%	0/ 1	0/ 1
	ruleset18	0%	0%	0/ 1	0/ 1
	ruleset19	0%	0%	1/ 2	0/ 2
	ruleset20	0%	0%	1/ 2	0/ 2
	ruleset21	0%	0%	0/ 1	0/ 1
	ruleset22	0%	0%	1/ 3	0/ 3
	ruleset24	0%	0%	0/ 3	0/ 3

COA Status Report for time 241108Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is not adopting course of action COA3_South

-- COA North Confidence Factor 0%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset1	0%	0%	0/ 1	0/ 1
	ruleset2	0%	0%	0/ 1	0/ 1
	ruleset3	0%	0%	0/ 1	0/ 1
	ruleset4	0%	0%	0/ 1	0/ 1
	ruleset5	0%	0%	0/ 2	0/ 2
	ruleset6	0%	0%	0/ 2	0/ 2
	ruleset7	0%	0%	0/ 3	0/ 3
	ruleset23	0%	0%	1/ 3	1/ 3

-- COA Split Confidence Factor 0%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset8	0%	0%	0/ 2	0/ 2
	ruleset9	0%	0%	0/ 2	0/ 2
	ruleset10	0%	0%	0/ 2	0/ 2
	ruleset11	0%	0%	1/ 2	1/ 2
	ruleset12	0%	0%	1/ 2	1/ 2
	ruleset13	0%	0%	0/ 2	0/ 2
	ruleset14	0%	0%	0/ 3	0/ 3
	ruleset15	0%	0%	0/ 1	0/ 1
	ruleset25	0%	0%	0/ 1	0/ 1
	ruleset26	0%	0%	1/ 2	1/ 2
	ruleset27	0%	0%	1/ 3	1/ 3
	ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 27%

--	RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
	ruleset16	27%	27%	1/ 1	1/ 1
	ruleset17	0%	0%	0/ 1	0/ 1
	ruleset18	0%	0%	0/ 1	0/ 1
	ruleset19	0%	0%	1/ 2	1/ 2
	ruleset20	0%	0%	1/ 2	1/ 2
	ruleset21	0%	0%	0/ 1	0/ 1
	ruleset22	0%	0%	1/ 3	1/ 3
	ruleset24	0%	0%	0/ 3	0/ 3

COA Status Report for time 241112Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is adopting course of action COA3_South

-- COA North Confidence Factor 0%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	0%	0%	2/ 3	1/ 3

-- COA Split Confidence Factor -36%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	0%	0%	0/ 2	0/ 2
ruleset9	0%	0%	0/ 2	0/ 2
ruleset10	0%	0%	0/ 2	0/ 2
ruleset11	13%	0%	2/ 2	1/ 2
ruleset12	0%	0%	1/ 2	1/ 2
ruleset13	0%	0%	1/ 2	0/ 2
ruleset14	0%	0%	0/ 3	0/ 3
ruleset15	0%	0%	0/ 1	0/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	-45%	0%	2/ 2	1/ 2
ruleset27	0%	0%	2/ 3	1/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 70%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	27%	27%	1/ 1	1/ 1
ruleset17	27%	0%	1/ 1	0/ 1
ruleset18	0%	0%	0/ 1	0/ 1
ruleset19	45%	0%	2/ 2	1/ 2
ruleset20	0%	0%	1/ 2	1/ 2
ruleset21	0%	0%	0/ 1	0/ 1
ruleset22	0%	0%	2/ 3	1/ 3
ruleset24	0%	0%	0/ 3	0/ 3

COA Status Report for time 241116Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is adopting course of action COA3_South

-- COA North Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1

ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	-81%	0%	3/ 3	2/ 3

-- COA Split Confidence Factor -70%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	0%	0%	0/ 2	0/ 2
ruleset9	0%	0%	0/ 2	0/ 2
ruleset10	0%	0%	0/ 2	0/ 2
ruleset11	13%	13%	2/ 2	2/ 2
ruleset12	13%	0%	2/ 2	1/ 2
ruleset13	13%	0%	2/ 2	1/ 2
ruleset14	0%	0%	0/ 3	0/ 3
ruleset15	45%	0%	1/ 1	0/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	-45%	-45%	2/ 2	2/ 2
ruleset27	-81%	0%	3/ 3	2/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 98%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	27%	27%	1/ 1	1/ 1
ruleset17	27%	27%	1/ 1	1/ 1
ruleset18	27%	0%	1/ 1	0/ 1
ruleset19	45%	45%	2/ 2	2/ 2
ruleset20	45%	0%	2/ 2	1/ 2
ruleset21	45%	0%	1/ 1	0/ 1
ruleset22	81%	0%	3/ 3	2/ 3
ruleset24	0%	0%	0/ 3	0/ 3

COA Status Report for time 241120Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is adopting course of action COA3_South

-- COA North Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2

ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	-81%	-81%	3/ 3	3/ 3

-- COA Split Confidence Factor -70%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	0%	0%	0/ 2	0/ 2
ruleset9	0%	0%	0/ 2	0/ 2
ruleset10	0%	0%	0/ 2	0/ 2
ruleset11	13%	13%	2/ 2	2/ 2
ruleset12	13%	13%	2/ 2	2/ 2
ruleset13	13%	13%	2/ 2	2/ 2
ruleset14	0%	0%	0/ 3	0/ 3
ruleset15	45%	45%	1/ 1	1/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	-45%	-45%	2/ 2	2/ 2
ruleset27	-81%	-81%	3/ 3	3/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 98%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	27%	27%	1/ 1	1/ 1
ruleset17	27%	27%	1/ 1	1/ 1
ruleset18	27%	27%	1/ 1	1/ 1
ruleset19	45%	45%	2/ 2	2/ 2
ruleset20	45%	45%	2/ 2	2/ 2
ruleset21	45%	45%	1/ 1	1/ 1
ruleset22	81%	81%	3/ 3	3/ 3
ruleset24	0%	0%	0/ 3	0/ 3

COA Status Report for time 241124Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is adopting course of action COA3_South

-- COA North Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	-81%	-81%	3/ 3	3/ 3

-- COA Split Confidence Factor -70%

-- RS	Current	Prev	Succ	Prev

Name	CF	CF	Rules	Rules
ruleset8	0%	0%	0/ 2	0/ 2
ruleset9	0%	0%	0/ 2	0/ 2
ruleset10	0%	0%	0/ 2	0/ 2
ruleset11	13%	13%	2/ 2	2/ 2
ruleset12	13%	13%	2/ 2	2/ 2
ruleset13	13%	13%	2/ 2	2/ 2
ruleset14	0%	0%	0/ 3	0/ 3
ruleset15	45%	45%	1/ 1	1/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	-45%	-45%	2/ 2	2/ 2
ruleset27	-81%	-81%	3/ 3	3/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 98%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	27%	27%	1/ 1	1/ 1
ruleset17	27%	27%	1/ 1	1/ 1
ruleset18	27%	27%	1/ 1	1/ 1
ruleset19	45%	45%	2/ 2	2/ 2
ruleset20	45%	45%	2/ 2	2/ 2
ruleset21	45%	45%	1/ 1	1/ 1
ruleset22	81%	81%	3/ 3	3/ 3
ruleset24	0%	0%	0/ 3	0/ 3

COA Status Report for time 241128Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is adopting course of action COA3_South

-- COA North Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	-81%	-81%	3/ 3	3/ 3

-- COA Split Confidence Factor -70%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	0%	0%	0/ 2	0/ 2
ruleset9	0%	0%	0/ 2	0/ 2
ruleset10	0%	0%	0/ 2	0/ 2
ruleset11	13%	13%	2/ 2	2/ 2

ruleset12	13%	13%	2/ 2	2/ 2
ruleset13	13%	13%	2/ 2	2/ 2
ruleset14	0%	0%	0/ 3	0/ 3
ruleset15	45%	45%	1/ 1	1/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	-45%	-45%	2/ 2	2/ 2
ruleset27	-81%	-81%	3/ 3	3/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 98%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	27%	27%	1/ 1	1/ 1
ruleset17	27%	27%	1/ 1	1/ 1
ruleset18	27%	27%	1/ 1	1/ 1
ruleset19	45%	45%	2/ 2	2/ 2
ruleset20	45%	45%	2/ 2	2/ 2
ruleset21	45%	45%	1/ 1	1/ 1
ruleset22	81%	81%	3/ 3	3/ 3
ruleset24	0%	0%	0/ 3	0/ 3

COA Status Report for time 241132Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is adopting course of action COA3_South

-- COA North Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	-81%	-81%	3/ 3	3/ 3

-- COA Split Confidence Factor -70%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	0%	0%	0/ 2	0/ 2
ruleset9	0%	0%	0/ 2	0/ 2
ruleset10	0%	0%	0/ 2	0/ 2
ruleset11	13%	13%	2/ 2	2/ 2
ruleset12	13%	13%	2/ 2	2/ 2
ruleset13	13%	13%	2/ 2	2/ 2
ruleset14	0%	0%	0/ 3	0/ 3
ruleset15	45%	45%	1/ 1	1/ 1
ruleset25	0%	0%	0/ 1	0/ 1

ruleset26	-45%	-45%	2/ 2	2/ 2
ruleset27	-81%	-81%	3/ 3	3/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 98%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	27%	27%	1/ 1	1/ 1
ruleset17	27%	27%	1/ 1	1/ 1
ruleset18	27%	27%	1/ 1	1/ 1
ruleset19	45%	45%	2/ 2	2/ 2
ruleset20	45%	45%	2/ 2	2/ 2
ruleset21	45%	45%	1/ 1	1/ 1
ruleset22	81%	81%	3/ 3	3/ 3
ruleset24	0%	0%	0/ 3	0/ 3

COA Status Report for time 241136Z

It appears that the OPFOR is not adopting course of action COA1_North
It appears that the OPFOR is not adopting course of action COA2_Split
It appears that the OPFOR is adopting course of action COA3_South

-- COA North Confidence Factor -81%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset1	0%	0%	0/ 1	0/ 1
ruleset2	0%	0%	0/ 1	0/ 1
ruleset3	0%	0%	0/ 1	0/ 1
ruleset4	0%	0%	0/ 1	0/ 1
ruleset5	0%	0%	0/ 2	0/ 2
ruleset6	0%	0%	0/ 2	0/ 2
ruleset7	0%	0%	0/ 3	0/ 3
ruleset23	-81%	-81%	3/ 3	3/ 3

-- COA Split Confidence Factor -70%

-- RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset8	0%	0%	0/ 2	0/ 2
ruleset9	0%	0%	0/ 2	0/ 2
ruleset10	0%	0%	0/ 2	0/ 2
ruleset11	13%	13%	2/ 2	2/ 2
ruleset12	13%	13%	2/ 2	2/ 2
ruleset13	13%	13%	2/ 2	2/ 2
ruleset14	0%	0%	0/ 3	0/ 3
ruleset15	45%	45%	1/ 1	1/ 1
ruleset25	0%	0%	0/ 1	0/ 1
ruleset26	-45%	-45%	2/ 2	2/ 2
ruleset27	-81%	-81%	3/ 3	3/ 3
ruleset28	0%	0%	0/ 3	0/ 3

-- COA South Confidence Factor 98%

--

RS Name	Current CF	Prev CF	Succ Rules	Prev Rules
ruleset16	27%	27%	1/ 1	1/ 1
ruleset17	27%	27%	1/ 1	1/ 1
ruleset18	27%	27%	1/ 1	1/ 1
ruleset19	45%	45%	2/ 2	2/ 2
ruleset20	45%	45%	2/ 2	2/ 2
ruleset21	45%	45%	1/ 1	1/ 1
ruleset22	81%	81%	3/ 3	3/ 3
ruleset24	0%	0%	0/ 3	0/ 3

APPENDIX D

VALIDATION SCENARIO

The purpose of the validation of the S2A2 was to determin if the S2A2 is produced the same assessment as the expert or S2. Specifically, the validation phase of the experiment looked to answer two questions about the system. Did the S2A2 produce the correct assessment? Is the S2A2 stable? To answer these questions 9 separate scenarios were used.

Scenario Used to Validate the S2A2

The specific scenario used to validate the S2A2 consisted of a mechanized infantry battalion conducting a deliberate defense against an attacking motorized rifle brigade (MRB) at the national training center. The MRB attacked from the west to the east. COA 1 was a reversed wedge with a first echelon consisting of an armor battalion in the north and a motorized rifle battalion in the south. The second echelon consisted of two motorized rifle battalions along the northern avenue of approach. COA 2 used a two up and two back formation with the first echelon consisting of an armor battalion in the north and a motorized rifle battalion in the south. The second echelon consisted of a motorized rifle battalion in the north and a motorized rifle battalion in the south. COA 3 used a three up and one back formation with the first echelon consisting of a motorized rifle battalion in the north, an armor battalion in the center and a motorized rifle battalion in the south. The second echelon consisted of a motorized rifle battalion in the north. A graphical representation of the OPFOR course of action is at Figures 5.

The friendly force COA 1 consisted of an armor company in a counter-reconnaissance role forward (west) of the main defensive belt. The main defensive belt consisted of a mechanized company in the north and a mechanized company in the south. An armor company served as the reserve. COA 2 consisted of an armor company and mechanized company in the north, an armor company (+) in the south and a mechanized company (-) as the reserve. COA 3 consisted of an armor company (+) in the north, an armor company and a mechanized company in the south and a mechanized company (-) as the reserve. In all three COAs reconnaissance assets consisting of 10 scout teams, 3 ground surveillance radars and 2 M2A2s (from the division cavalry), were forward of the main defensive belt. Each of the OPFOR COAs was run against each of the friendly force COAs to get a total of nine runs. A graphical representation of the friendly force course of action is at Figures 6.

Indicators, rules and rule sets were constructed to determine which COA the enemy was employing. The following table outlines the indicators for the validation scenario.

Table 12

Validation Scenario Indicators

INDICATOR	COUNT	EQUIPMENT	NAI	COA
1	1	BRDM	1 BRDM1	1
2	1	BRDM	2 BRDM1	1
3	1	BMP	BMP PLTN1	1
4	1	BMP	BMP PLTS1	1
5	15	BTR-70	3BN1	1
7	15	BTR-70	1 BN BTR1	1
8	8	T80	1 BN TK1	1
9	8	T80	1 BN TK2	2
10	1	BMP	BMP PLTN2	2
11	1	BMP	BMP PLTS2	2
12	1	BRDM	1BRDM2	2
13	1	BRDM	2BRDM2	2
14	1	BRDM	3BRDM2	2
15	1	BRDM	4BRDM2	2
16	22	T-80	TK BN 2	2
16	22	T-80	TK BN 1	1
19	15	BTR-70	2BN2	2
20	15	BTR-70	3BN2	2
21	1	BRDM	2BRDM3	3
22	1	BRDM	2BRDN3	3
23	1	BRDM	2BRDS3	3
24	1	BMP	BMP PLTS3	3
25	1	BMP	BMP PLTN3	3
26	22	T80	TK BN3	3
27	8	T80	1BN TK3	3
28	15	BTR-70	1BN BTR3	3
29	15	BTR-70	2BN3	3
30	15	BTR-70	3BN3	3
32	15	BTR-70	1BN BTR2	2
33	15	BTR-70	2BN1	1

The table below outlines the rules for the validation scenario.

Table 13

Validation Scenario Rules

RULE	INDICATOR	TIME WINDOW	CERTAINTY FACTOR	COA SUPPORTED
1	I3 V I4	60 Minutes	100%	1
2	I1 ∧ I2	60 Minutes	100%	1
3	I7 V I8	60 Minutes	100%	1
6	I33	30 Minutes	100%	1
7	I5	30 Minutes	100%	1
8	I17	60 Minutes	100%	1
9	I10 V I11	60 Minutes	100%	2
10	I12 V I13 V I14 V I15	60 Minutes	100%	2
13	I9 V 32	180 Minutes	100%	2
14	I16	30 Minutes	100%	2
15	I19	30 Minutes	100%	2
16	I20	30 Minutes	100%	2
17	I24 V I25	60 Minutes	100%	3
18	I22 V I23 V I21	60 Minutes	100%	3
19	I26	30 Minutes	100%	3
20	I28 V I27	180 Minutes	100%	3
21	I29	30 Minutes	100%	3
22	I30	30 Minutes	100%	3

The following table outlines the rule sets for the validation scenario.

Table 14

Validation Scenario Rule Sets

RULE SETS	RULES	CERTAINTY FACTOR	COA SUPPORTED
1	R1	10%	1
2	R2	10%	1
3	R8	30%	1
6	R3	70%	1
7	R6	30%	1
8	R7	30%	1
9	R9	10%	2
10	R10	10%	2
11	R14	30%	2
14	R3	70%	2
15	R15	30%	2
16	R16	30%	2
17	R17	10%	3
18	R18	10%	3
19	R19	70%	3
20	R20	50%	3
21	R21	70%	3
22	R22	30%	3

The following table outlines the COAs for the validation scenario.

Table 15

Validation Scenario COAs

COA	RULE SETS
1	RS1, RS2, RS3, RS6, RS7, RS8
2	RS9, RS10, RS11, RS14, RS15, RS16

3	RS17, RS18, RS19, RS20, RS21, RS22,

APPENDIX E

S2A2 VALIDATION TEST OUTPUT

This appendix contains the last report generated by the S2A2 for each of the nine runs.

Run 11

```
COA Status Report for 020350Z

It appears that the OPFOR is adopting course of action COA2_COA 2
It appears that the OPFOR is not adopting course of action COA3_COA3
It appears that the OPFOR is adopting course of action COA1_COA 1

-- COA COA 2 Confidence Factor    43%
 --     RS           Current      Prev  Succ   Prev
      Name           CF     CF    Rules Rules
           RR BMP2         10%          10%        1/ 1   1/ 1
          RR BRDM2         10%          10%        1/ 1   1/ 1
            TK BN2          0%           0%        0/ 1   0/ 1
             1 BN2          0%           0%        0/ 1   0/ 1
             2 BN2          0%           0%        0/ 1   0/ 1
             3 BN2         30%          30%        1/ 1   1/ 1


-- COA COA3 Confidence Factor    19%
 --     RS           Current      Prev  Succ   Prev
      Name           CF     CF    Rules Rules
           RR BMP3         10%          10%        1/ 1   1/ 1
          RR BRDM3         10%          10%        1/ 1   1/ 1
            TK BN3          0%           0%        0/ 1   0/ 1
             1 BN3          0%           0%        0/ 1   0/ 1
             2 BN3          0%           0%        0/ 1   0/ 1
             3 BN3          0%           0%        0/ 1   0/ 1


-- COA COA 1 Confidence Factor    88%
 --     RS           Current      Prev  Succ   Prev
      Name           CF     CF    Rules Rules
           RR BMP1         10%          10%        1/ 1   1/ 1
          RR BRDM1         10%          10%        1/ 1   1/ 1
            TK BN1         30%          30%        1/ 1   1/ 1
             1 BN1         70%          70%        1/ 1   1/ 1
             2 BN1         30%          30%        1/ 1   1/ 1
             3 BN1          0%           0%        0/ 1   0/ 1
```

Run 12

```
COA Status Report for 020520Z

It appears that the OPFOR is not adopting course of action COA2_COA 2
It appears that the OPFOR is adopting course of action COA3_COA3
It appears that the OPFOR is adopting course of action COA1_COA 1
```

```
-- COA COA 2 Confidence Factor     19%
 --    RS           Current      Prev  Succ  Prev
      Name          CF     CF     Rules Rules
           RR BMP2         10%         10%        1/ 1  1/ 1
         RR BRDM2         10%         10%        1/ 1  1/ 1
           TK BN2          0%          0%        0/ 1  0/ 1
            1 BN2          0%          0%        0/ 1  0/ 1
            2 BN2          0%          0%        0/ 1  0/ 1
            3 BN2          0%          0%        0/ 1  0/ 1


-- COA COA3 Confidence Factor     59%
 --    RS           Current      Prev  Succ  Prev
      Name          CF     CF     Rules Rules
           RR BMP3         10%         10%        1/ 1  1/ 1
         RR BRDM3         10%         10%        1/ 1  1/ 1
           TK BN3          0%          0%        0/ 1  0/ 1
            1 BN3         50%         50%        1/ 1  1/ 1
            2 BN3          0%          0%        0/ 1  0/ 1
            3 BN3          0%          0%        0/ 1  0/ 1


-- COA COA 1 Confidence Factor     88%
 --    RS           Current      Prev  Succ  Prev
      Name          CF     CF     Rules Rules
           RR BMP1         10%         10%        1/ 1  1/ 1
         RR BRDM1         10%         10%        1/ 1  1/ 1
           TK BN1         30%         30%        1/ 1  1/ 1
            1 BN1         70%         70%        1/ 1  1/ 1
            2 BN1         30%         30%        1/ 1  1/ 1
            3 BN1          0%          0%        0/ 1  0/ 1
```

Run 13

```
COA Status Report for 020520Z

It appears that the OPFOR is adopting course of action COA2_COA 2
It appears that the OPFOR is not adopting course of action COA3_COA3
It appears that the OPFOR is adopting course of action COA1_COA 1

-- COA COA 2 Confidence Factor     43%
 --    RS           Current      Prev  Succ  Prev
      Name          CF     CF     Rules Rules
           RR BMP2         10%         10%        1/ 1  1/ 1
         RR BRDM2         10%         10%        1/ 1  1/ 1
           TK BN2          0%          0%        0/ 1  0/ 1
            1 BN2          0%          0%        0/ 1  0/ 1
            2 BN2          0%          0%        0/ 1  0/ 1
            3 BN2         30%         30%        1/ 1  1/ 1


-- COA COA3 Confidence Factor     19%
 --    RS           Current      Prev  Succ  Prev
      Name          CF     CF     Rules Rules
           RR BMP3         10%         10%        1/ 1  1/ 1
         RR BRDM3         10%         10%        1/ 1  1/ 1
           TK BN3          0%          0%        0/ 1  0/ 1
```

```
                 1 BN3            0%           0%          0/ 1   0/ 1
                 2 BN3            0%           0%          0/ 1   0/ 1
                 3 BN3            0%           0%          0/ 1   0/ 1


-- COA COA 1 Confidence Factor     88%
 --     RS           Current      Prev  Succ  Prev
        Name          CF     CF    Rules Rules
               RR BMP1           10%          10%          1/ 1   1/ 1
              RR BRDM1           10%          10%          1/ 1   1/ 1
                TK BN1           30%          30%          1/ 1   1/ 1
                 1 BN1           70%          70%          1/ 1   1/ 1
                 2 BN1           30%          30%          1/ 1   1/ 1
                 3 BN1            0%           0%          0/ 1   0/ 1
```

Run 21

```
COA Status Report for 020400Z

It appears that the OPFOR is adopting course of action COA2_COA 2
It appears that the OPFOR is adopting course of action COA3_COA3
It appears that the OPFOR is adopting course of action COA1_COA 1

-- COA COA 2 Confidence Factor     82%
 --     RS           Current      Prev  Succ  Prev
        Name          CF     CF    Rules Rules
               RR BMP2           10%          10%          1/ 1   1/ 1
              RR BRDM2           10%          10%          1/ 1   1/ 1
                TK BN2            0%           0%          0/ 1   0/ 1
                 1 BN2           70%          70%          1/ 1   1/ 1
                 2 BN2           30%          30%          1/ 1   1/ 1
                 3 BN2            0%           0%          0/ 1   0/ 1


-- COA COA3 Confidence Factor     59%
 --     RS           Current      Prev  Succ  Prev
        Name          CF     CF    Rules Rules
               RR BMP3           10%          10%          1/ 1   1/ 1
              RR BRDM3           10%          10%          1/ 1   1/ 1
                TK BN3            0%           0%          0/ 1   0/ 1
                 1 BN3           50%          50%          1/ 1   1/ 1
                 2 BN3            0%           0%          0/ 1   0/ 1
                 3 BN3            0%           0%          0/ 1   0/ 1


-- COA COA 1 Confidence Factor     60%
 --     RS           Current      Prev  Succ  Prev
        Name          CF     CF    Rules Rules
               RR BMP1           10%          10%          1/ 1   1/ 1
              RR BRDM1           10%          10%          1/ 1   1/ 1
                TK BN1           30%          30%          1/ 1   1/ 1
                 1 BN1            0%           0%          0/ 1   0/ 1
                 2 BN1           30%          30%          1/ 1   1/ 1
                 3 BN1            0%           0%          0/ 1   0/ 1
```

Run 22

```
COA Status Report for 020520Z

It appears that the OPFOR is adopting course of action COA2_COA 2
It appears that the OPFOR is adopting course of action COA3_COA3
It appears that the OPFOR is adopting course of action COA1_COA 1

-- COA COA 2 Confidence Factor     88%
 --     RS           Current      Prev  Succ   Prev
        Name           CF     CF    Rules Rules
             RR BMP2          10%          10%         1/ 1   1/ 1
            RR BRDM2          10%          10%         1/ 1   1/ 1
              TK BN2          30%          30%         1/ 1   1/ 1
               1 BN2          70%          70%         1/ 1   1/ 1
               2 BN2          30%          30%         1/ 1   1/ 1
               3 BN2           0%           0%         0/ 1   0/ 1


-- COA COA3 Confidence Factor     59%
 --     RS           Current      Prev  Succ   Prev
        Name           CF     CF    Rules Rules
             RR BMP3          10%          10%         1/ 1   1/ 1
            RR BRDM3          10%          10%         1/ 1   1/ 1
              TK BN3           0%           0%         0/ 1   0/ 1
               1 BN3          50%          50%         1/ 1   1/ 1
               2 BN3           0%           0%         0/ 1   0/ 1
               3 BN3           0%           0%         0/ 1   0/ 1


-- COA COA 1 Confidence Factor     60%
 --     RS           Current      Prev  Succ   Prev
        Name           CF     CF    Rules Rules
             RR BMP1          10%          10%         1/ 1   1/ 1
            RR BRDM1          10%          10%         1/ 1   1/ 1
              TK BN1          30%          30%         1/ 1   1/ 1
               1 BN1           0%           0%         0/ 1   0/ 1
               2 BN1          30%          30%         1/ 1   1/ 1
               3 BN1           0%           0%         0/ 1   0/ 1
```

Run 23

```
COA Status Report for 020520Z

It appears that the OPFOR is adopting course of action COA2_COA 2
It appears that the OPFOR is adopting course of action COA3_COA3
It appears that the OPFOR is not adopting course of action COA1_COA 1

-- COA COA 2 Confidence Factor     89%
 --     RS           Current      Prev  Succ   Prev
```

```
     Name          CF     CF     Rules Rules
          RR BMP2          0%           0%        0/ 1   0/ 1
        RR BRDM2           0%           0%        0/ 1   0/ 1
          TK BN2          30%          30%        1/ 1   1/ 1
           1 BN2          70%          70%        1/ 1   1/ 1
           2 BN2          30%          30%        1/ 1   1/ 1
           3 BN2          30%          30%        1/ 1   1/ 1


-- COA COA3 Confidence Factor     69%
 --    RS          Current      Prev  Succ  Prev
     Name          CF     CF     Rules Rules
          RR BMP3         10%          10%        1/ 1   1/ 1
        RR BRDM3           0%           0%        0/ 1   0/ 1
          TK BN3           0%           0%        0/ 1   0/ 1
           1 BN3          50%          50%        1/ 1   1/ 1
           2 BN3           0%           0%        0/ 1   0/ 1
           3 BN3          30%          30%        1/ 1   1/ 1


-- COA COA 1 Confidence Factor      0%
 --    RS          Current      Prev  Succ  Prev
     Name          CF     CF     Rules Rules
          RR BMP1          0%           0%        0/ 1   0/ 1
        RR BRDM1           0%           0%        0/ 1   0/ 1
          TK BN1           0%           0%        0/ 1   0/ 1
           1 BN1           0%           0%        0/ 1   0/ 1
           2 BN1           0%           0%        0/ 1   0/ 1
           3 BN1           0%           0%        0/ 1   0/ 1
```

Run 31

```
COA Status Report for 020520Z

It appears that the OPFOR is adopting course of action COA2_COA 2
It appears that the OPFOR is adopting course of action COA3_COA3
It appears that the OPFOR is not adopting course of action COA1_COA 1

-- COA COA 2 Confidence Factor     30%
 --    RS          Current      Prev  Succ  Prev
     Name          CF     CF     Rules Rules
          RR BMP2          0%           0%        0/ 1   0/ 1
        RR BRDM2           0%           0%        0/ 1   0/ 1
          TK BN2           0%           0%        0/ 1   0/ 1
           1 BN2           0%           0%        0/ 1   0/ 1
           2 BN2          30%          30%        1/ 1   1/ 1
           3 BN2           0%           0%        0/ 1   0/ 1


-- COA COA3 Confidence Factor     95%
 --    RS          Current      Prev  Succ  Prev
     Name          CF     CF     Rules Rules
          RR BMP3         10%          10%        1/ 1   1/ 1
        RR BRDM3           0%           0%        0/ 1   0/ 1
```

```
             TK BN3          70%         70%         1/ 1   1/ 1
              1 BN3          50%         50%         1/ 1   1/ 1
              2 BN3          70%         70%         1/ 1   1/ 1
              3 BN3           0%          0%         0/ 1   0/ 1


-- COA COA 1 Confidence Factor      0%
 --    RS           Current     Prev  Succ  Prev
      Name          CF     CF    Rules Rules
             RR BMP1          0%          0%         0/ 1   0/ 1
            RR BRDM1          0%          0%         0/ 1   0/ 1
              TK BN1          0%          0%         0/ 1   0/ 1
               1 BN1          0%          0%         0/ 1   0/ 1
               2 BN1          0%          0%         0/ 1   0/ 1
               3 BN1          0%          0%         0/ 1   0/ 1
```

Run 32

```
COA Status Report for 020500Z

It appears that the OPFOR is not adopting course of action COA2_COA 2
It appears that the OPFOR is adopting course of action COA3_COA3
It appears that the OPFOR is not adopting course of action COA1_COA 1

-- COA COA 2 Confidence Factor     30%
 --    RS           Current     Prev  Succ  Prev
      Name          CF     CF    Rules Rules
             RR BMP2          0%          0%         0/ 1   0/ 1
            RR BRDM2          0%          0%         0/ 1   0/ 1
              TK BN2          0%          0%         0/ 1   0/ 1
               1 BN2          0%          0%         0/ 1   0/ 1
               2 BN2          0%          0%         0/ 1   0/ 1
               3 BN2         30%         30%         1/ 1   1/ 1


-- COA COA3 Confidence Factor     90%
 --    RS           Current     Prev  Succ  Prev
      Name          CF     CF    Rules Rules
             RR BMP3          0%          0%         0/ 1   0/ 1
            RR BRDM3          0%          0%         0/ 1   0/ 1
              TK BN3         70%         70%         1/ 1   1/ 1
               1 BN3          0%          0%         0/ 1   0/ 1
               2 BN3         70%         70%         1/ 1   1/ 1
               3 BN3          0%          0%         0/ 1   0/ 1


-- COA COA 1 Confidence Factor      0%
 --    RS           Current     Prev  Succ  Prev
      Name          CF     CF    Rules Rules
             RR BMP1          0%          0%         0/ 1   0/ 1
            RR BRDM1          0%          0%         0/ 1   0/ 1
              TK BN1          0%          0%         0/ 1   0/ 1
               1 BN1          0%          0%         0/ 1   0/ 1
               2 BN1          0%          0%         0/ 1   0/ 1
               3 BN1          0%          0%         0/ 1   0/ 1
```

Run 33

```
COA Status Report for 020400Z

It appears that the OPFOR is not adopting course of action COA2_COA 2
It appears that the OPFOR is adopting course of action COA3_COA3
It appears that the OPFOR is not adopting course of action COA1_COA 1

-- COA COA 2 Confidence Factor     30%
 --     RS          Current      Prev  Succ   Prev
      Name            CF    CF     Rules Rules
           RR BMP2          0%          0%       0/ 1   0/ 1
          RR BRDM2          0%          0%       0/ 1   0/ 1
            TK BN2          0%          0%       0/ 1   0/ 1
             1 BN2          0%          0%       0/ 1   0/ 1
             2 BN2          0%          0%       0/ 1   0/ 1
             3 BN2         30%         30%       1/ 1   1/ 1


-- COA COA3 Confidence Factor     90%
 --     RS          Current      Prev  Succ   Prev
      Name            CF    CF     Rules Rules
           RR BMP3         10%         10%       1/ 1   1/ 1
          RR BRDM3          0%          0%       0/ 1   0/ 1
            TK BN3         70%         70%       1/ 1   1/ 1
             1 BN3         50%         50%       1/ 1   1/ 1
             2 BN3          0%          0%       0/ 1   0/ 1
             3 BN3         30%         30%       1/ 1   1/ 1


-- COA COA 1 Confidence Factor      0%
 --     RS          Current      Prev  Succ   Prev
      Name            CF    CF     Rules Rules
           RR BMP1          0%          0%       0/ 1   0/ 1
          RR BRDM1          0%          0%       0/ 1   0/ 1
            TK BN1          0%          0%       0/ 1   0/ 1
             1 BN1          0%          0%       0/ 1   0/ 1
             2 BN1          0%          0%       0/ 1   0/ 1
             3 BN1          0%          0%       0/ 1   0/ 1
```

APPENDIX F

S2A2 STABILITY DATA VALUES

Run 11
10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 75, 75, 75, 75, 75, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88

Run 12
10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 75, 75, 75, 75, 75, 75, 75, 75, 75, 75, 75, 75, 75, 75, 75, 75, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88

Run 13
10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 75, 75, 75, 75, 75, 75, 75, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88

Run 21
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 19, 19, 19, 19, 19, 43, 43, 43, 43, 43, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82, 82

Run 22
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 78, 78, 78, 78, 78, 78, 78, 78, 78, 78, 78, 78, 82, 82, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88, 88

Run 31
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 10, 10, 10, 10, 10, 10, 10, 10, 10, 10, 73, 73, 73, 73, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95 95, 95, 95, 95, 95, 95, 95, 95, 95, 95, 95

Run 32
0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 70, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90

Run 33
0, 0, 10, 10, 10, 10, 10, 10, 68, 68, 68, 68, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90, 90

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